THE UNIVERSITY OF ALBERTA

Stratigraphy of the Glauconitic member (Mannville Group), Medicine River Field and adjacent areas, south-central Alberta

by

(C) Rudolph S. Strobl

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Supervisor

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Date October 9, 1986

ABSTRACT

A regional stratigraphic study and a detailed sedimentological study (the Medicine River Field substudy), make up a two part investigation of the Glauconitic member. The Glauconitic member consists largely of shoreface and shallow marine sandstones which conformably overlie marine mudstones of the Calcareous member; the two members making up the middle Mannville formation.

Based on examination of core from 78 wells and logs from 1 to 5 wells per section, two lithosomes, the Sheet Sands and the Hoadley Bar, are distinguished in the Medicine River Field. The Sheet Sands lithosome is generally less than 15m thick. It consists of offshore marine mudstones at the base, passing upwards through interbedded sandstones, siltstones and mudstones of the lower shoreface, to middle and upper shoreface amalgamated sandstones, to a lagoonal mudstone and overlying coal. This lithosome formed during the rapid progradation northwards of a series of wave-dominated deltas. Considerable variation in thickness, and very limited lateral extent of beds, indicate localized depositional conditions. Brackish-water indicators include synaeresis cracks, spiral-shaped trace fossils, and pyritic and sideritic concretions.

The Hoadley Bar lithosome lies north of and parallel to the Sheet Sands. It displays a similar shallowing upward trend but consists of 10 to 25m of generally uninterrupted, fine to medium grained sandstones; in contrast to the thinner, usually less than 10m, units of very fine to fine grained amalgamated sandstones of the Sheet Sands lithosome. A widespread coal seam, the Glauconitic coal, directly overlies both lithosomes.

A channelling episode preceded deposition of the Glauconitic coal and commonly produced fining upward sandy sequences. In some of these sequences, permeable sandstones, 15 to 25m thick, make good gas reservoirs. A younger channelling episode post-dated deposition of the Glauconitic coal. Muddy sequences, up to 40m thick, filled these latter channels creating extensive stratigraphic traps. Both channel filling episodes are considered to have been estuarine in nature, following downcutting of up to 40m.

The regional stratigraphic study was based on more than 1900 wells over 400 townships. Other lithosomes identified in this study, namely the Bigoray and Upper Mannville Bars, are

located north of and parallel to the Hoadley Bar lithosome. These three features indicate shoreline trends more than 200 km long, oriented southwest-northeast.

Widespread regressive conditions followed deposition of the Glauconitic member. There is a distinct hingeline between shallow marine sandstones of the Glauconitic member and the offshore marine mudstones of a sub-basin to the north. Conglomerates located in the Hoadley Bar lithosome, and the major Glauconitic sandstones, were derived from a fluvial source to the southwest, reflecting a strong tectonic influence throughout south-central Alberta.

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I. INTRODUCTION

In southern Alberta, the Glauconitic member and the underlying Calcareous member make up the Lower Cretaceous, middle Mannville formation. The Medicine River Field, an important oil producer until the late 1970's, produced light gravity oils from sheet sandstones of the Glauconitic member. The first objective of this thesis is to give a better understanding of the sedimentology, stratigraphy and reservoir character of the sandstones in the Medicine River Field. The Medicine River Field was chosen for detailed examination because of exceptional well control (up to 5 wells per section) and because of abundant core data (up to 4 cored wells per section). Results from this study may prove useful for the discovery and development of similar oil fields producing from the Glauconitic member in other areas of Alberta.

The second objective is regional in nature, in which the stratigraphy of the Glauconitic member is mapped and discussed within a study block of approximately 400 townships (see Figure 1). By identifying major lithologic units (or lithosomes) within this larger study area, a better understanding of depositional trends and the full extent of regional shoreline development can be gained. A lithosome is defined as a rock unit of uniform lithologic character, readily distinguished from adjacent intertonguing units. Delineation of the major lithosomes in this study gives a regional perspective and may prove to be useful for exploration purposes.

MEDICINE RIVER FIELD SUBSTUDY

This detailed substudy covers 9 townships and includes the description of 78 available cores. An integrated approach was adopted in the examination of the core samples. In addition to interpreting sedimentary structures and bedding characteristics, trace fossils and palynology were used as aids in interpreting genesis. Detailed stratigraphic correlation based on geophysical well logs was then done to map the paleogeography and depositional trends in areas adjacent to the field.

Two episodes of channelling are of considerable importance in the study area. The older episode consists of channel complexes dominated by fining-upward sandy sequences which are commonly good gas reservoirs. A younger channelling episode identified in the study area is

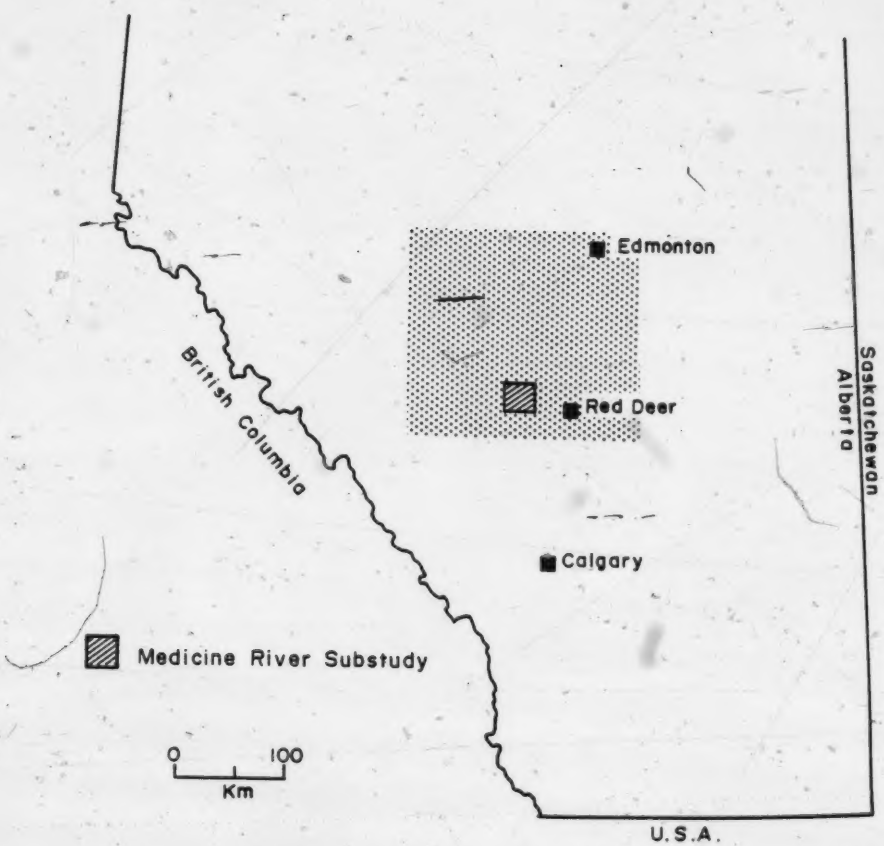


Figure 1. Location map of study areas.

dominated by muddy infilling, and acts as a stratigraphic trap for sheet and bar sandstones of the Glauconitic member. The nature and orientation of both types of channel complexes, therefore, are important to oil and gas exploration. Documentation of these channels may be useful in evaluating partially explored, laterally equivalent strata.

A computer database was created with information from 216 wells, each penetrating the Glauconitic member. Isopach and structure contour maps and three-dimensional perspective diagrams were derived from this database. Due to variable lithologies and the presence of channel complexes, blanking routines and digitizing techniques were required for computer generation of these maps and diagrams. The geometry of the reservoir units, sand thickness variation, fluid distributions and structural controls on the Medicine River Field are illustrated and discussed, based on these maps.

REGIONAL STUDY

Due to the lack of published stratigraphic studies of the Glauconitic member in central and southern Alberta, the author initiated a regional mapping project using more than 1900 wells. This project incorporates a study block from Tp. 35, Rge. 19W4M in the southeast corner to Tp. 54, Rge. 14W5M in the northwest corner (Figure 2). As a result of this mapping, three lithosomes consisting of thick barrier sandstones were delineated. These lithosomes are located immediately north of and parallel to the sheet sandstones of the Medicine River Field study area. Regional correlation and reconstruction of the depositional history of the Glauconitic member was based on these mapping results.

A coal seam identified as the Medicine River coal is widespread, and can be correlated over most of the study area. This coal seam lies 15 to 30 metres above the top of the Glauconitic member, and is an excellent datum. It is used to correlate the Glauconitic member on a regional scale, and also to help interpret the regional depositional history.

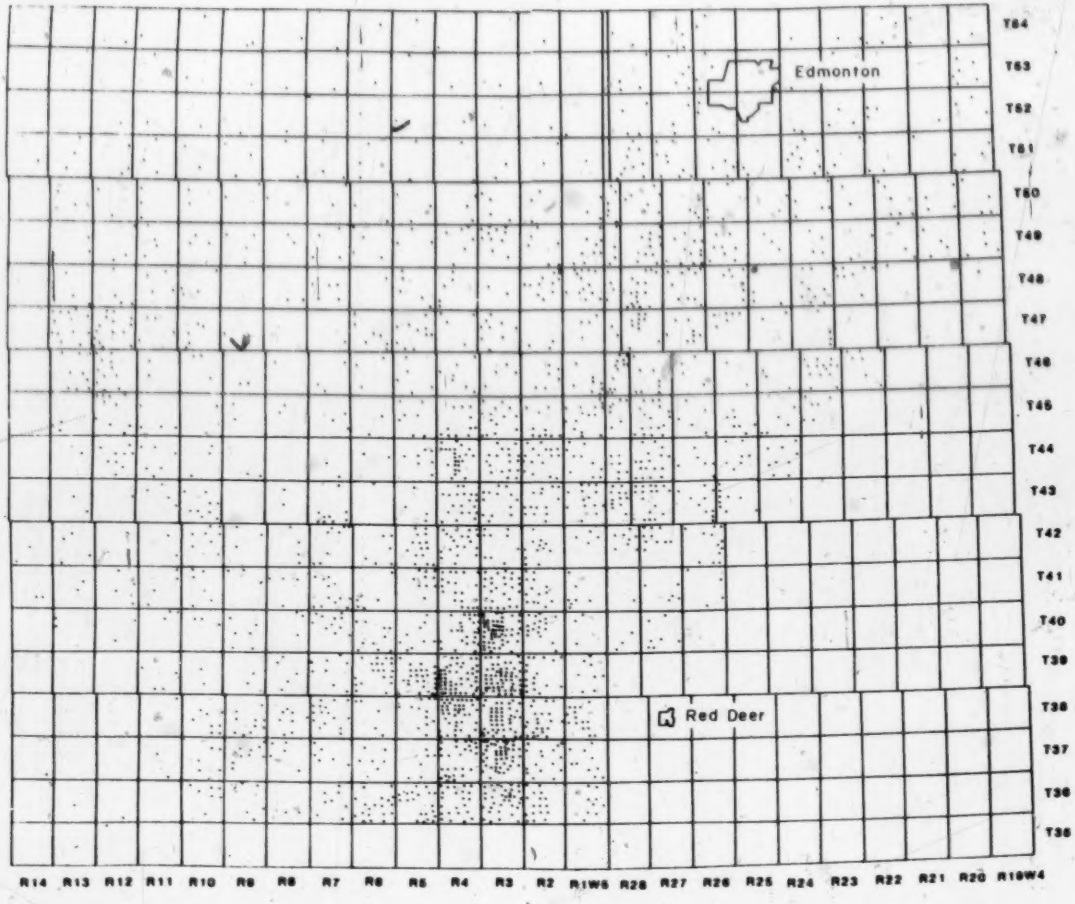


Figure 2. Location of wells used in the regional study.

II. PREVIOUS WORK

A. CORRELATION OF THE MANNVILLE GROUP

Numerous studies based on surface and subsurface data, from the Foothills to the Plains regions, have addressed local and basinwide correlation of the Mannville Group. A wide variety of correlative names (Figure 3) has led to some confusion and possible miscorrelation in some instances. The large number of names has caused some recent workers to simply divide the Mannville Group into three informal units: the lower, middle, and upper Mannville (O'Connell, 1985; Cant, in press). For regional mapping, the use of local names given to formations, members and other subunits of the Mannville Group were thought to be unnecessary. This simpler approach to correlation was favoured in this study.

HISTORY OF NAMES

Nauss(1945) introduced the name Mannville Formation in the Vermillion area for the continental and marine clastic sequence lying between the eroded Paleozoic surface below and the Colorado shales above.

Badgley(1952) raised the Mannville Formation of the Edmonton and Lloydminster areas to group status. He divided the group into three formations: the McMurray, Clearwater and Grand Rapids Formations, in ascending order. Detrital sediments deposited in depressions of the Paleozoic surface were named the Deville Formation, and excluded from the Mannville Group.

Glaister(1959) divided the group into the "Lower" and "Upper" Mannville Formations based on mineralogical differences. The boundary between the two units was placed at the top of the Calcareous member or Ostracode zone, which is a widespread marker in central and southern Alberta. The change in mineralogy from dominantly quartzose sediments with minor chert in the Lower Mannville, to quartzose sediments containing abundant chert and minor volcanic detritus and feldspars in the Upper Mannville, was an important distinction. The appearance of feldspar and lithic detritus reflects a major period of tectonism accompanied by volcanism along the western basin boundary (Williams, 1963).

Williams(1963) extended Badgley's (1952) nomenclature from northeastern Alberta to central Alberta, but included the Deville Formation as the basal member of the McMurray

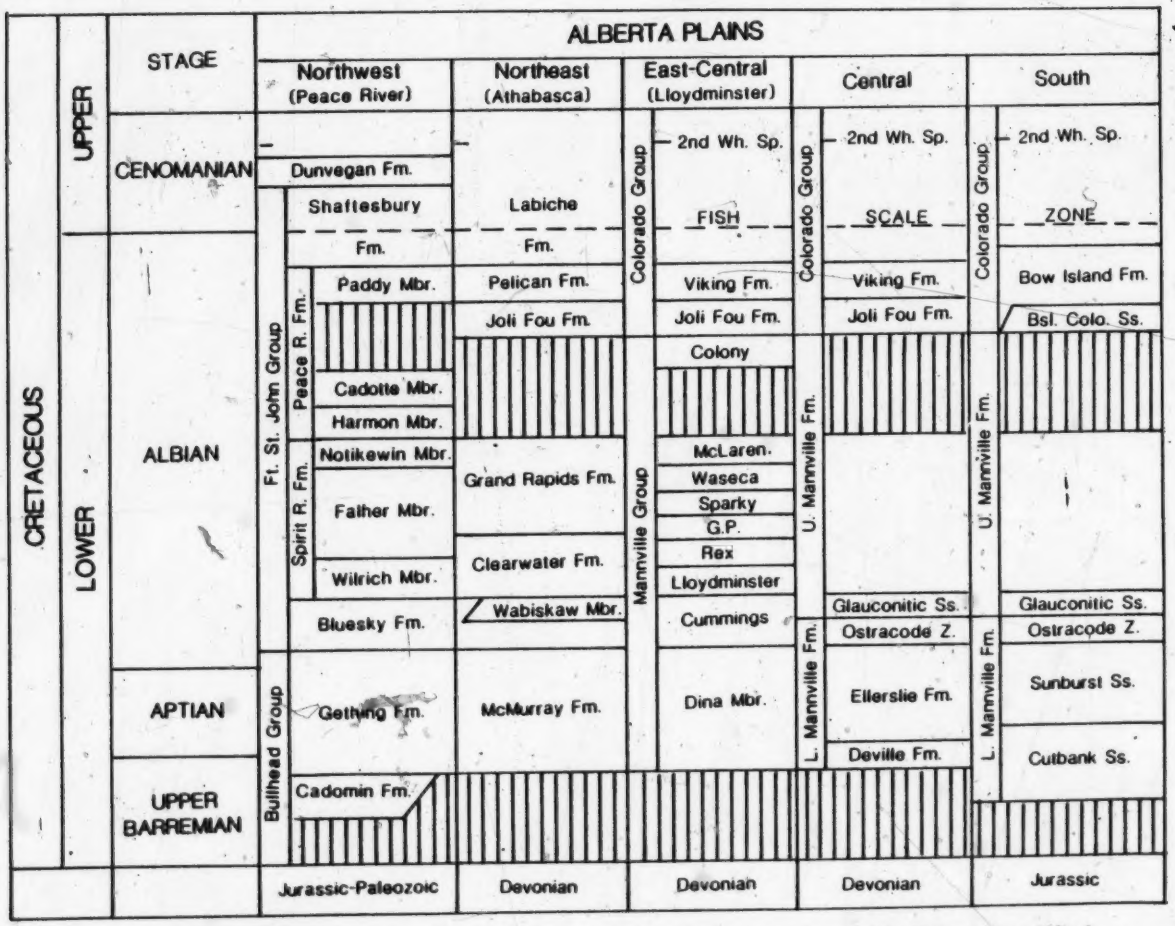


Figure 3. Correlation diagram showing subdivisions of the Mannville Group (modified after Rudkin, 1964).

Formation. Williams named the middle part of the McMurray Formation the Ellerslie member, after a unit described by Hunt(1950) which lies at a similar stratigraphic level. Williams named the upper part of the McMurray Formation the Calcareous member, which was proposed initially by Glaister(1959).

Rudkin(1964) divided the Mannville Group into upper and lower formations, on the basis of electric geophysical logs and other available subsurface data for the Plains region. Rudkin's divisions are similar to those proposed by Glaister(1959).

Mellon(1967) accepted Rudkin's (1964) upper and lower divisions, but renamed the lower Mannville the McMurray Formation, after Williams(1963), and proposed the name Fort Augustus Formation for the upper Mannville. Mellon(1967) considered the Fort Augustus Formation to correlate with the Clearwater and Grand Rapids Formations of Williams(1963), but did not extend these names to central Alberta.

The names proposed by Williams(1963) and Mellon(1967) did not meet with widespread approval, however, and were not commonly used by subsequent researchers. The nomenclature and correlations made by Glaister(1959) and Rudkin(1964) appear to be favoured and are shown in Figure 3.

CORRELATION OF THE GLAUCONITIC MEMBER

Loranger(1951) introduced the term "Glauconitic sandstone" for the first major sandy sequence above the Ostracode zone in southern Alberta. Since then subsurface geologists have correlated the Glauconitic sandstone to the Bluesky Formation in northern and western Alberta, the Wabiskaw Formation in northeastern Alberta and the upper portion of the Cummings sandstone in east-central Alberta (Figure 3).

In addition to the numerous names in regional correlation, there has been a proliferation of names used in local areas. A sampling of terms include: the Glauconitic sandstone (Loranger, 1951; Rudkin, 1964; Herbaly, 1974; Tilley, 1982), the Glauconite sandstone (Conybeare, 1976; Chiang, 1985), the Glauconite sand (Holmes and Rivard, 1976), the Glauconite informal member (Jackson, 1985), the Islay, the Glauconitic, the Home sand, and the Kerhoff sandstone.

In this study, the term "Glauconitic member" was preferred to the array of names given above. The Glauconitic member consists of marine and marginal marine sandstones, but

also of sandstones and mudstones of channelling sequences, fine grained sandstones and mudstones of floodplain sequences, and mudstones of lagoonal sequences. The Glauconitic member is not always a well defined sandstone, as many of the above names would imply. Member status was given because it appears to be a unit which is mappable on a regional scale throughout central and southern Alberta.

SIMPLIFIED CORRELATION OF THE MANNVILLE GROUP

In the Lloydminster area, Vigrass(1977) informally subdivided the Mannville Group into lower, middle, and upper subgroups. Putnam(1982) used similar divisions based on genetic character of each unit. The lower Mannville unit was considered to consist mainly of valley-fill sequences; the middle Mannville unit to consist mainly of sheet sandstones deposited by repeated transgressive-regressive events; and the upper Mannville unit to consist mainly of coastal plain and shoreline sediments. O'Connell(1985) suggested similar subdivisions of the Mannville Group for the Lloydminster area, and proposed that the lower, middle, and upper Mannville units be given formation status. In Putnam's(1982) and O'Connell's(1985) divisions, the lower Mannville consisted of the Dina Formation, the middle Mannville consisted of the Cummings, Lloydminster, Rex, General Petroleum, and Sparky Formations, and the upper Mannville consisted of the Waseca, McLaren, and Colony Formations (Figure 3).

Jackson(1985) and Cant (in press) have suggested that the Mannville Group may be divided into lower, middle, and upper units on a basin-wide scale. Correlations and designated unit names proposed by Jackson (1985) will be used in this thesis (Figure 4).

The lower Mannville unit, which lies on the pre-Mannville unconformity, comprises a series of patchy, non-marine sandstones, shales, coals, and some conglomerates, and is commonly considered to represent fluvial, valley-fill deposits. The Lower Blairmore, Ellerslie, Cadomin, Gething, Gladstone, McMurray and Dina Formations are equivalents or partial equivalents of the lower Mannville (Jackson, 1985; Cant, in press).

The middle Mannville unit consists largely of shallow marine, shoreface, and estuarine sandstones, shales, and minor limestones. This unit includes the Calcareous member (Ostracode zone), and the Glauconitic member, and equivalents in the Bluesky Formation, the Wabiskaw Formation and the Cummings sandstone (Jackson,1985; Cant, in press).

The upper Mannville unit consists of both marine and non-marine sediments, and is the result of a major clastic input originating in southern Alberta, and prograding towards the north. This unit consists of coastal plain and fluvial sediments in southern Alberta (including the Blairmore and Beaver Mines Formations), shoreline and shallow marine sediments in central Alberta (including the Moosebar-Gates, Spirit River, Clearwater, Grand Rapids, and the Lloydminster to McLaren Formations), and totally marine sediments in the north (including the Loon River, Buckinghorse, and Clearwater Formations).

The simplified correlations proposed here, and the generalized depositional setting in each area are shown in Figure 4.

B. AGE DETERMINATION AND BIOSTRATIGRAPHY

Various sequences within the Mannville Group (and its Foothills equivalents) have been a popular subject of biostratigraphic research. Megafossil identification, micropaleontology and palynology have been the main basis for age assignments and biostratigraphic correlation. Because of the lack of diagnostic mega- and microfauna in many of the non-marine sequences, however, there have been differing interpretations of the ages, especially within the lower Mannville formation. More precise and conformable dating of mega- and microfaunal successions were achieved for marine deposits of the middle and upper Mannville formations.

In the Blairmore region of southwestern Alberta, Berry(1929a, b) recognised two distinctive megafloras, a non-dicotyledonous flora assigned to a "Lower Blairmore" unit and a dicotyledonous flora assigned to an "Upper Blairmore" unit. The age of the "Lower Blairmore" (or lower Mannville formation) based on the dominance of non-dicotyledonous flora, was taken as Late Aptian or Albian by Berry (1929a, b). Subsequent studies by McLearn(1932, 1945) in northeastern Alberta give Barremian and Aptian ages for the lower Mannville formation. Refinement of the biostratigraphy and estimation of ages of the Mannville Group were done in later studies using microfaunal, foraminiferal, and microfloral evidence by Loranger(1951), Bell(1956), Mellon and Wall(1956), and Glaister(1959). Based on these studies we can assume that most of the Mannville Group sediments are Upper Barremian to Middle Albian in age (Figure 5).

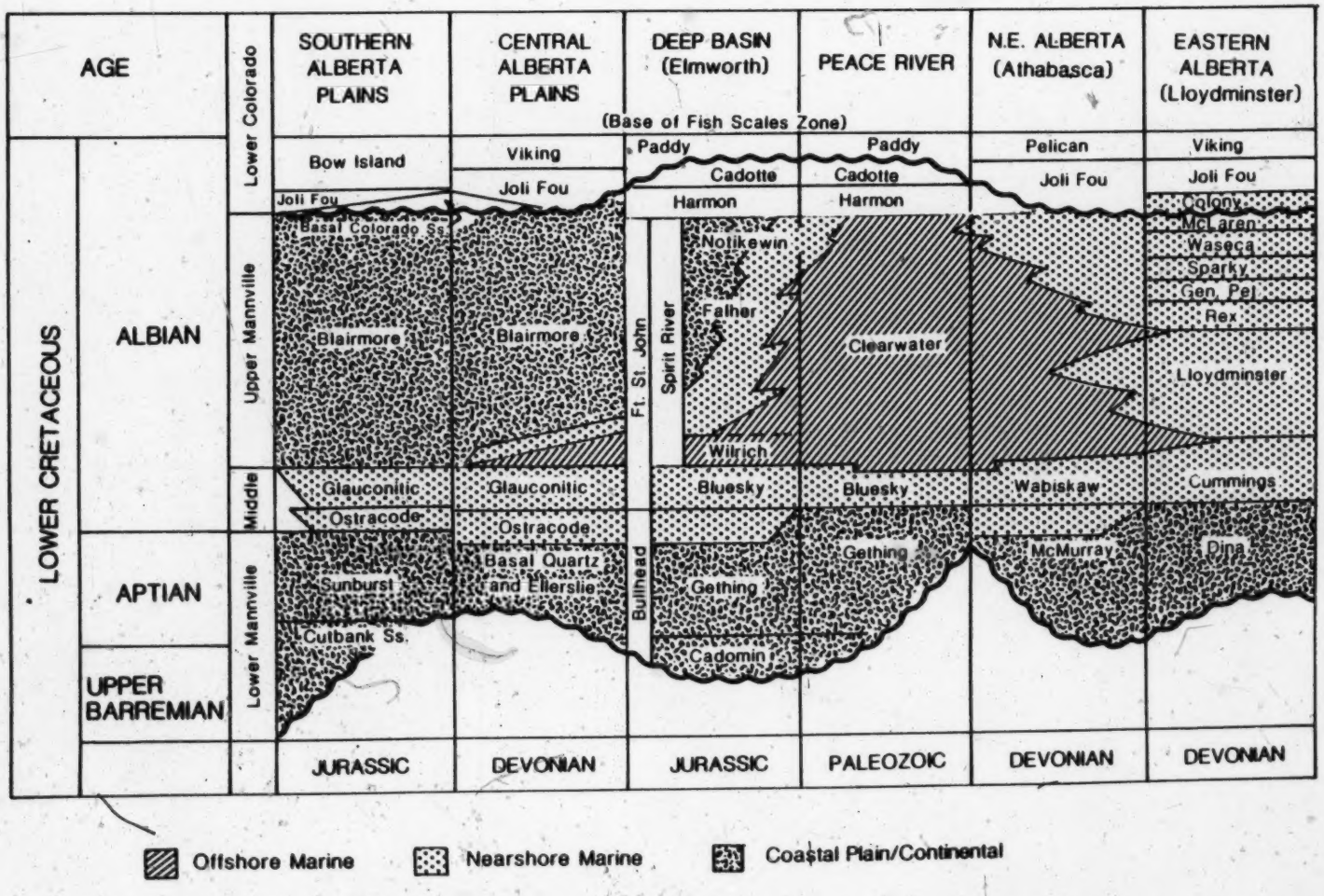


Figure 4. Simplified stratigraphic diagram of the Mannville Group (modified after Jackson, 1985).

The presence of primitive angiosperm pollen identified by Singh (1964,1971) and Pocock (1976), suggests that the age of the lower Mannville unit in most localities is latest Barremian to earliest Aptian (Figure 5). Burden (1984) is in agreement with these age interpretations but suggests diachronism of the lower Mannville sediments. Based on three terrestrial palynomorph assemblages, the lower Mannville unit in Alberta and the equivalent Kootenai strata in Montana, range from Late Barremian to earliest Albian in age, the younger sediments being in Montana, and the older sediments being in northeastern Alberta.

Middle Mannville marine mudstones sampled from the central and northern Alberta Foothills by McLean and Wall (1981) contain abundant foraminifera, ostracodes, charophytes, diatoms, and brachiopods. The faunal evidence in these sequences suggests an early Albian age. In north-central Alberta, Stelck and Kramers (1980) suggest a latest Early Albian age for sediments in the Grand Rapids Formation (upper Mannville) based on ammonites. Singh (1964) gives a similar age for upper Mannville strata in northeastern Alberta on the basis of palynology. The age boundaries presented in Figure 4 are the ones currently accepted within the Mannville Group by recent authors.

C. MINERALOGY OF THE MANNVILLE GROUP

Glaister (1959) and Williams (1963) were among the earliest researchers to formally recognize discrete mineralogical differences in the Mannville Group. Lower Mannville sediments were found to be dominantly quartzose, rarely containing chert, and without volcanic detritus. Much of these mature quartzose sediments were highly reworked, and were probably derived from the Precambrian craton along the eastern basin margin (Williams, 1963; O'Connell, 1985). Middle and upper Mannville sediments were found to be dominantly quartzose but containing abundant chert and volcanic detritus, including relatively immature feldspars. This abrupt change in mineralogy reflects the introduction of volcanic and plutonic sources in the west that accompanied tectonism during the Columbian Orogeny (Eisbacher and Gabrielse, 1975). The boundary between the lower and upper Mannville units was marked by the first appearance of chert and volcanic detritus (Glaister, 1959; Williams, 1963).

	McLearn (1945)			Mellon and Wall (1956)	Glaister (1959)				Pocock (1962)	Pocock (1976)	Singh (1964)	Singh (1971)	Carrigy (1973)	Stelck and Kramers (1981)	
Stage	Blairmore Alta.	Mountain Park Alta.	Athabasca R. Valley	Fort McMurray	Northwestern Montana	Southern Alberta	Central Alberta	Athabasca Area	Western Canada	Central Alta.	Athabasca River	Central Alta.	Fort McMurray	Athabasca River	Central Alta.
Albian	Blairmore Group	Mountain Park	Grand Rapids	Clearwater and Wabiskaw	unnamed upper Kootenay	unnamed upper Blairmore	unnamed upper Mannville	Grand Rapids: Clearwater: unnamed; Wabiskaw; unnamed	Glauconite	Grand Rapids	Grand Rapids	Grand Rapids	Grand Rapids	Grand Rapids	Grand Rapids; Clearwater; Glauconite; Calcareous
			Clearwater	U. McMurray	Calcareous	Calcareous	Glauconite			Clearwater	Clearwater	Clearwater		Clearwater	
					unnamed	unnamed lower Blairmore	Ellerslie	McMurray		Wabiskaw	Wabiskaw	Wabiskaw	Wabiskaw	Wabiskaw	
Aptian		Luscar	McMurray		Sunburst					Calcareous	McMurray	Calcareous	McMurray	McMurray	Ellerslie
										Ellerslie		Ellerslie			
		Cadomin			Cut Bank	Blairmore Conglomerate			Calcareous	Deville					
Upper Barremian	Kootenay	Nikanassin									Deville	Deville	Pre-McMurray		
Hauterivian Barremian						Kootenay			Quartz Ss.						
Berriasian Valanginian									Deville						

Figure 5. Nomenclatural history of the Mannville Group (after Burden, 1984).

MINERALOGY OF THE GLAUCONITIC MEMBER

Workman (1958) considered the Glauconitic member in southeastern Alberta to consist of fine grained to very fine grained sandstones with low chert content and containing only detrital glauconite. Conybeare (1976) described the Glauconitic member in southwestern Alberta as chert-rich, fine grained to coarse grained sandstones with indigenous glauconite. These studies were somewhat in agreement with the results of Rapson (1965), who found an increase in chert content towards the west, indicating a western source for the chert detritus. Throughout the entire basin, much of the detrital material found in the middle Mannville was derived from the western basin margin, based on the abundance of fresh igneous and metamorphic fragments in many of the sandstones (O'Connell, 1985). Many of these sandstones are argillaceous, due in part to the breakdown of abundant feldspars amongst the detrital grains (Badgley, 1952).

Most studies of the Glauconitic member in southern Alberta describe a dominantly quartzose sandstone containing variable amounts of chert fragments, and minor amounts of sedimentary and volcanic fragments. Studies by Holmes and Rivard (1976), Mellon (1967), and Thomas (1978) cite a predominance of volcanic rock fragments over sedimentary rock fragments. Studies by Reichenbach (1981) and Tilley (1982) found that sedimentary rock fragments predominated over volcanic fragments. In most studies, glauconite within the Glauconitic member was a minor constituent, and in some cases was not present.

D. OTHER STUDIES OF THE GLAUCONITIC MEMBER

Recent studies of the Glauconitic member in southern and central Alberta offer a variety of depositional interpretations, ranging from marine and marginal marine environments to coastal plain and fluvial. Most available studies are limited to individual oil and gas fields.

In the Suffield area, Holmes and Rivard (1977) and Tilley (1982) suggest a marginal marine depositional setting for Glauconitic member sandstones. They describe shoreface marine sandbodies deposited along barrier island complexes. In the Little Bow area, Hermanson (1982) describes marine sheet and offshore bar sandstones locally cut by later channelling episodes. In the Cherhill area, Chow (1979) describes marine sheet sandstones and suggests a subtidal marine setting. Chiang (1981, 1985) and Reichenbach (1982) describe a barrier and back-barrier depositional setting for the Glauconitic member sandstones for the Hoadley and

Medicine River Fields, respectively, near Alhambra.

Floodplain and fluvial depositional environments are described by Brown (1976) in the Turin area, by Herbaly (1974) and Farshori (1983b) in the Countess Field area, and by Hradsky and Griffin (1984) in the Taber area. Regional studies such as those by Herbaly (1974), Jackson (1985) and James (1985) also give floodplain and fluvial interpretations to much of the Glauconitic member in southern Alberta.

Perhaps the diversity of interpretations from these studies reflects the complex stratigraphy associated with marginal marine depositional settings and migrating shoreline positions. The thickness of the Glauconitic member sandstones ranges from 6 to 9 metres to greater than 30 metres, and changes markedly over relatively short distances (Workman, 1958; Conybeare, 1976). Hermanson (1982) and Jackson (1985) suggest that the Glauconitic member in southern Alberta was deposited during northward progradation of a widespread coastal plain. A series of nearshore marine sandbodies with sheet and bar geometries were laid down along progressively younger shorelines. The coastal plain was extensively dissected by channel sequences having a general southeast to northwest orientation. Each northward shift in the shoreline position caused channels to extend northward and to incise into previously deposited marine sequences (Hermanson, 1982). This simple explanation accounts for the diversity of depositional environments observed, and in part, for the variable thickness of Glauconitic member sandstones.

III. STRATIGRAPHY

A. STRUCTURAL CONTROLS AND BASIC STRATIGRAPHY

A wedge of Mesozoic detrital sediment thickens dramatically towards the west (Figure 6). Subsidence of the basin was greatest in the west due to loading and/or tectonic influences along the western basin margin, as a result of the Late Jurassic to Early Cretaceous Columbian Orogeny. A rising mountain belt was a major source of the Mesozoic detritals. Generally, the rate of subsidence increased to the southwest resulting in a corresponding thickening of the clastic wedge in that direction. The Mannville Group is a part of this clastic assemblage, which ranges from Late Jurassic to Early Cretaceous in age (Figure 6). The Mannville Group is a sequence laid down in a newly developing foreland basin.

Structural controls imposed by subsidence to the southwest, and the resulting asymmetrical geometry of the basin, influenced sedimentation during all of Mannville time (Figure 7). During middle and upper Mannville times additional structural controls were introduced. Major depocentres or sub-basins such as the northern sub-basin, resulting from subsidence over the Peace River Arch (Jackson, 1985), and the Salt Collapse Low (Putnam, 1982; Jackson, 1985), resulting from subsidence over collapsing Devonian strata, may also have been important controlling factors in Mannville Group sedimentation (Figure 8).

B. GEOLOGICAL SETTING OF THE MANNVILLE GROUP

The Mannville Group and equivalent strata are present over most of the Western Canadian Sedimentary Basin. The entire Mannville sequence was deposited within a broad shallow basin that opened towards the northwest. It was bounded in the west by the rising Cordillera (Columbian Orogeny) and in the east by the Precambrian Shield (Figure 9). Putnam (1982), O'Connell (1985) and Cant (in press) divide the Mannville Group into 3 units, the lower, middle, and upper Mannville. The depositional history of each unit is summarized below.

LOWER MANNVILLE DEPOSITION

The lower Mannville sediments lie directly on the pre-Mannville unconformity. The unconformity was created during a period of sustained regional uplift and tilting. West-dipping

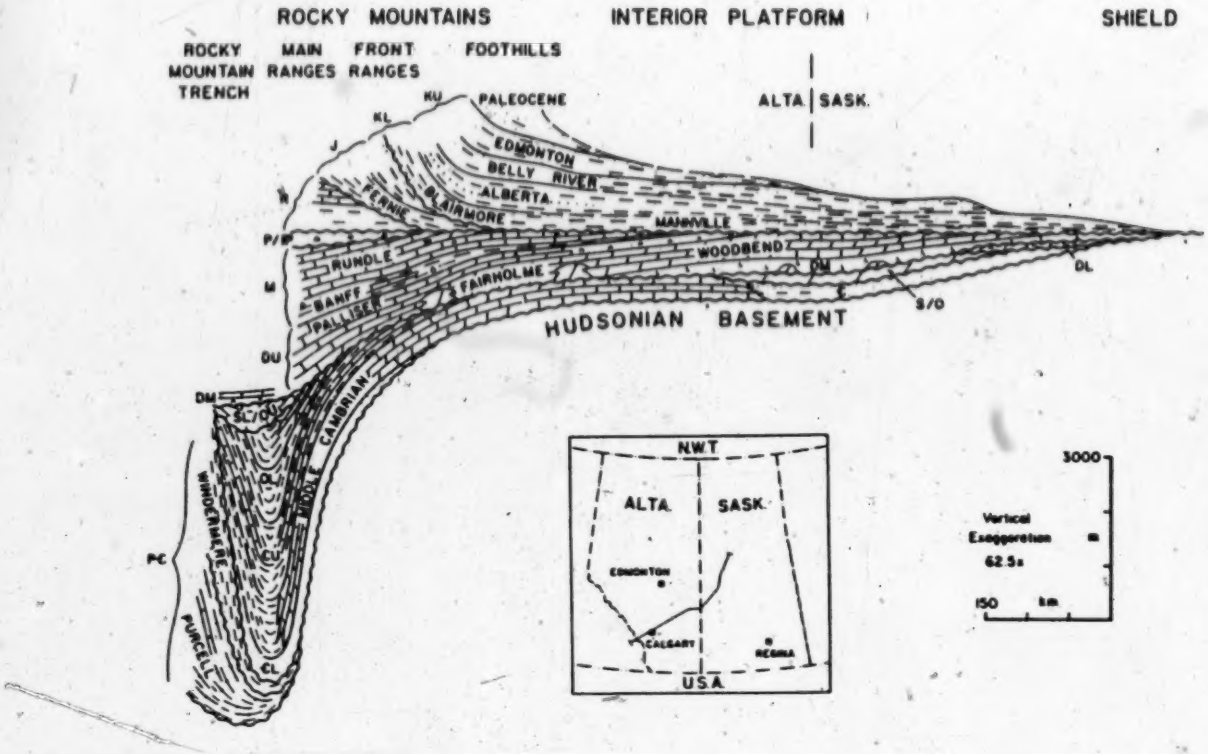


Figure 6. Schematic diagram illustrating the wedge of Mesozoic clastics thickening towards the west (after Perkins, 1984).

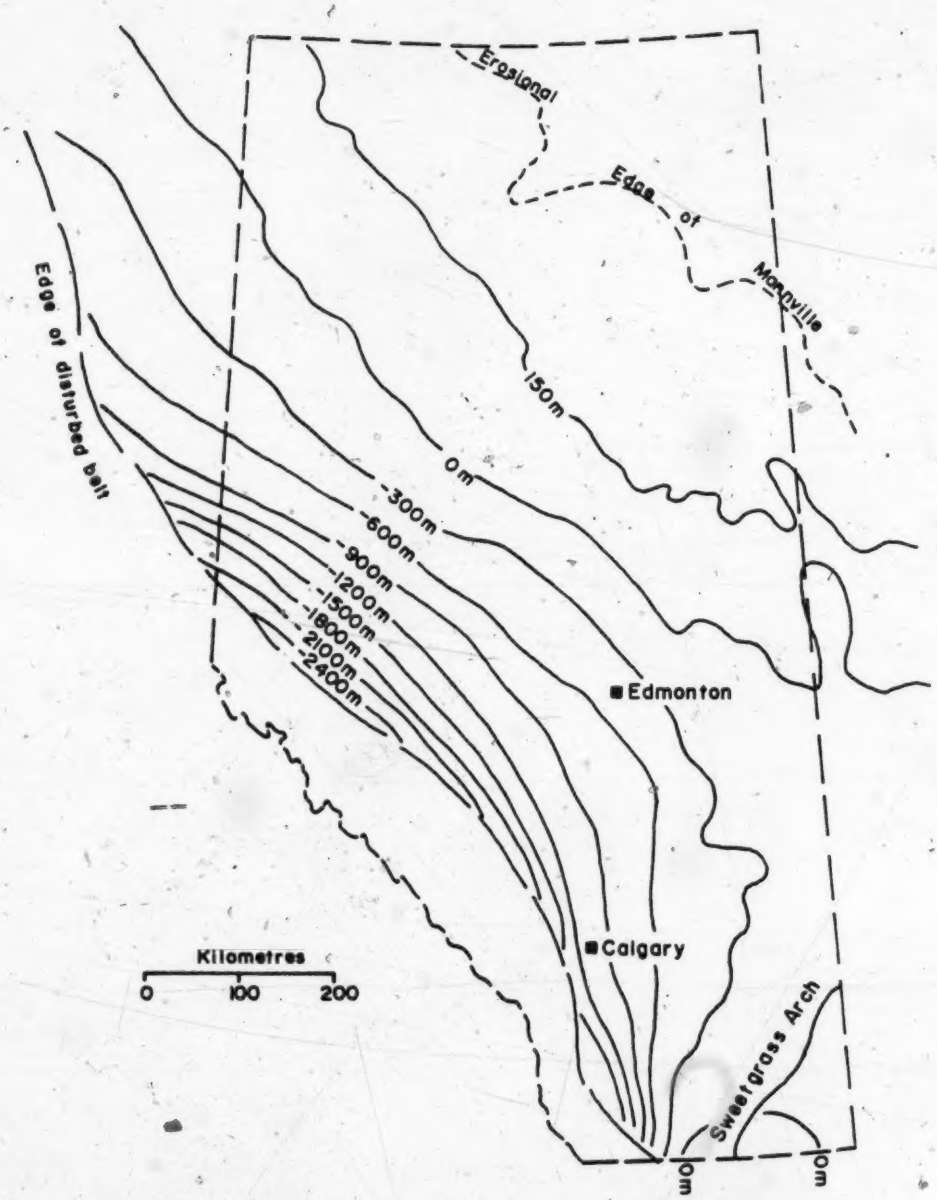


Figure 7. Structure contour map of the pre-Mannville unconformity showing the asymmetrical geometry of the basin and increasing dip towards the southwest (modified after Jackson, 1985).

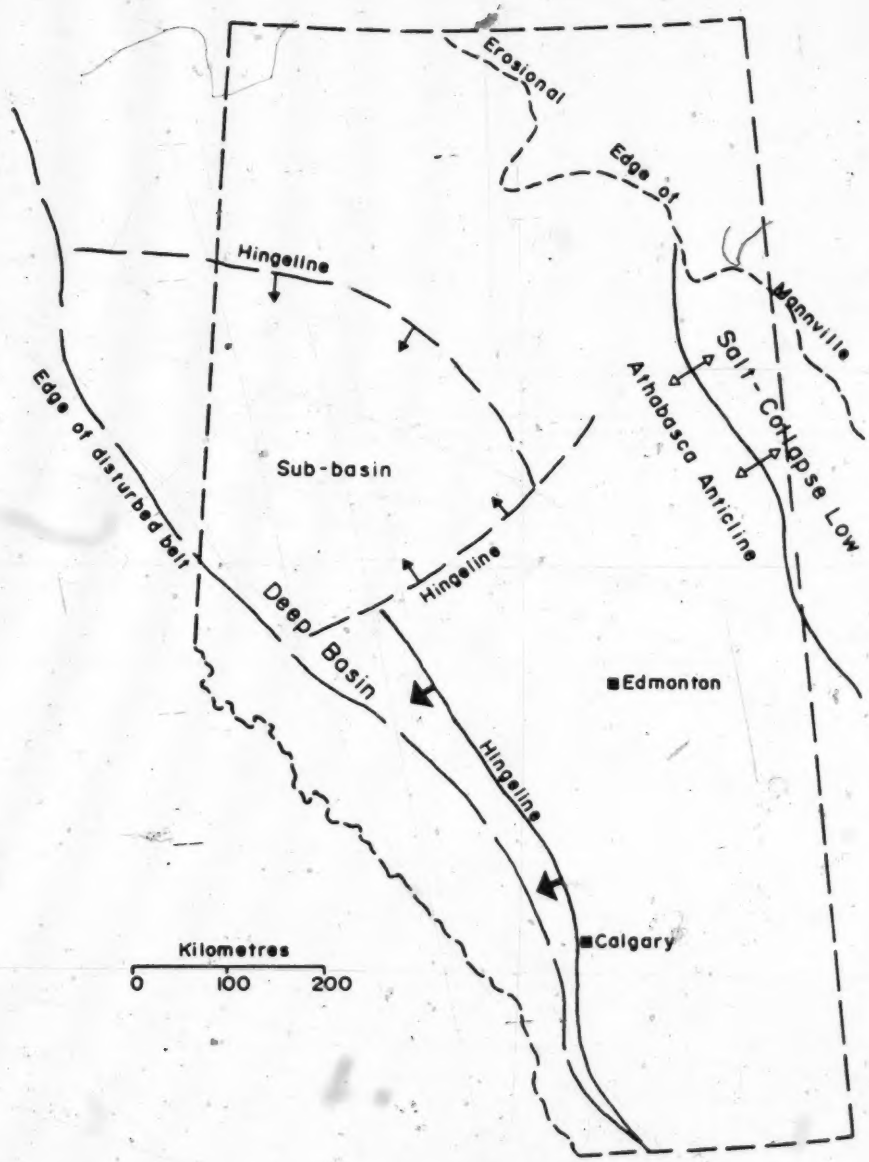
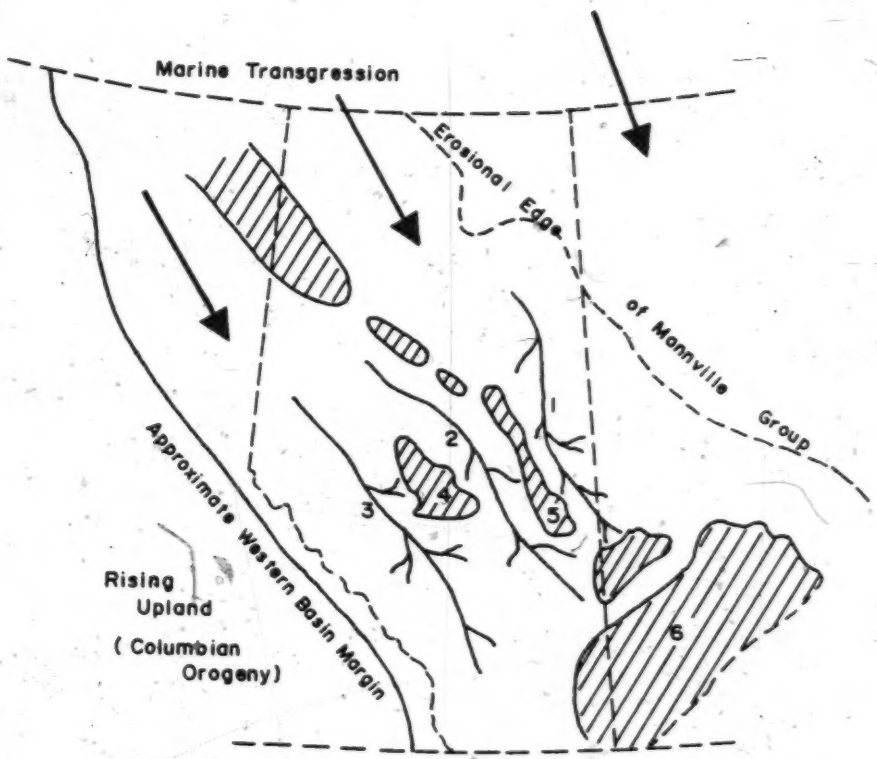


Figure 8. Major sub-basins and structural trends influencing middle and upper Mannville sedimentation (modified after Jackson, 1985).



1 St. Paul System
2 Edmonton System
3 Spirit River System
4 Pembina High
5 Wainwright Ridge
6 North Battleford High

Figure 9. Approximate Mannville paleogeography at the Aptian-Albian boundary showing basin outlines and topographically high areas, with inferred fluvial drainage (modified after McLean and Wall, 1981; Stott, 1982; and O'Connell, 1985).

rock units, ranging from very early Cretaceous in the west to Devonian in the east, subcrop along this unconformity (Figure 10). Large scale erosion and incised drainage on the unconformity surface led to the development of southeast to northwest trending ridge and valley systems. Three major valley systems, from east to west, the St. Paul and Edmonton systems (separated by the Wainwright Ridge), identified by Williams (1963), and the Spirit River system identified by McLean (1977), were prominent during deposition of the lower Mannville sequence. Rivers within these valleys flowed to the north and northwest from upland areas in the south (Figure 9). Topographic relief on the unconformity was up to 130 metres (Williams, 1963) and therefore had a major effect on sedimentation.

Fluvial deposits in these valleys are considered to be aggradational valley fill sequences (Weimer, 1974; O'Connell, 1985), and were deposited in response to a rise in base level during a marine transgression originating from the northwest (Williams, 1963; McLean and Wall, 1981). Some of the valley fill is considered Jurassic (Hopkins, 1981), but Lower Cretaceous ages were determined in most studies. In the Spirit River system very coarse grained fluvial sediments were deposited, represented by the Cadomin conglomerate, in a series of braided river complexes (McLean, 1977). Elsewhere the broad valleys were filled by finer fluvial sediments, represented by the Gething, Gladstone, and McMurray Formations. Both the Gladstone and the McMurray Formations contain point bar sequences with lateral accretion surfaces, suggesting that these are meandering river deposits (Taylor and Walker, 1984; Mossop and Flach, 1983). Traced northward, the marine influence appears in the form of estuarine sediments, particularly in the upper parts of the lower Mannville (Mossop and Flach, 1983). Southern Alberta was the last area to undergo marine transgression. Valley fill sequences in the south include the Dalhousie, Moulton, Sunburst, Detrital, Basal Quartz, and Ellerslie sandstones. These intervals are dominently non-marine, but marine affinities may be present in the upper portions. Lower Mannville deposition was brought to an end by a slowdown in input of coarse clastic sediments, combined with eustatic sea level rise (Cant, in press).

MIDDLE MANNVILLE DEPOSITION

In some places, the boundary between the lower and middle Mannville is transitional and is difficult to place. In the Peace River area, for instance, the boundary between the Gething Formation (upper Mannville) and the Bluesky Formation (middle Mannville) is

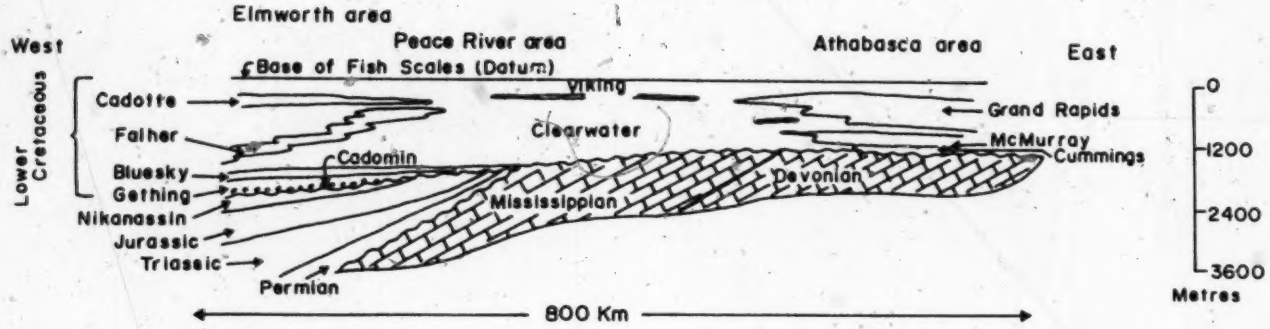


Figure 10. Diagrammatic cross-section across central Alberta (after Masters, 1985).

somewhat arbitrary. Generally, the middle Mannville is composed of marine to marginal marine sediments which blanket the basin. It is usually a thin (less than 30 metres) and diachronous sheet of sandstone, shale and minor limestone. Middle Mannville sequences include the Calcareous member (Ostracode zone), the Glauconitic member (Glauconitic sandstone), the Bluesky Formation, the Wabiskaw Formation, and the Cummings sandstone (Figure 4).

Throughout Alberta, much of middle Mannville deposition is characterised by southwest to northeast or west to east shoreline trends. In northeastern Alberta some northwest to southeast trends reflect the draping of sediments over underlying Paleozoic highs such as the Wainwright Ridge (O'Connell, 1985). Relatively thick and extensive littoral sandbodies were commonly formed over slightly elevated areas of the Paleozoic surface (Rudkin, 1964; Cant, in press). The Bigoray Bar and the Upper Mannville Bar lithosomes (this paper) are examples of southwest to northeast oriented barrier trends over the Pembina High (Figure 9).

Sediments laid down in response to the transgressing seas mark the beginning of middle Mannville deposition. Fresh-water mixing by river systems originating in southern Alberta resulted in brackish water conditions over relatively large areas. The Calcareous member or Ostracode zone is considered to have formed in this environment (Singh, 1964; Burden, 1982). The transgression inundated much of central Alberta but one can only speculate as to the maximum marine advance in southern Alberta. McLean and Wall (1981) suggest that the transgression reached as far south as the Fall Creek area, based on a diverse assemblage of marine fauna identified from the middle Mannville sequence. Taylor and Walker (1984) found evidence to support marine conditions as far south as the Elbow River-Bragg Creek area. Some studies such as those by Jackson (1985) and Hayes (1986), speculated that the transgression reached the Canada-U.S.A. border, based largely on the presence of *Muderongia* sp. in mudstone samples. A diverse assemblage of dinoflagellates and other marine fauna such as foraminifera, diatoms and brachiopods in central and northern Alberta offer convincing evidence of normal marine conditions. In southern Alberta, however, the presence of *Muderongia* sp. by itself is less convincing. *Muderongia* sp. appears to have been very tolerant of low salinities and may have been present in drowned river valleys, coastal lakes, and delta distributaries (Singh, pers.comm.). Farshori (1983a) concludes that much of the Ostracode zone in southeastern Alberta consists of lacustrine sequences, agreeing in part with the interpretation given by Singh. An alternate interpretation to that of Jackson (1985) and Hayes

(1986) is shown in Figure 11.

In central and southern Alberta, Jackson (1985) suggests that the Glauconitic member, which overlies the Calcareous member or Ostracode zone, was deposited during the turnaround of the southward transgression. He considers the Glauconitic member to represent a major northward progradation which returned shorelines to central Alberta. This would suggest that the Glauconitic member sandstones of southern Alberta are slightly younger than the Bluesky, Cummings, and Wabiskaw sandstones of the Peace River, Athabasca, and Lloydminster areas, respectively. These latter sandstones may be time equivalents to the upper portions of the Calcareous member or Ostracode zone in southern Alberta.

Extensive shoreface and barrier island sequences of the Glauconitic member were deposited in the Pembina and Hoadley areas (this study). Marine mudstones of the Clearwater Formation were deposited to the north of the barrier island sequences indicating that offshore-marine conditions prevailed in that direction (Chiang, 1985; Jackson, 1985).

Barrier island and deltaic sequences of the Hoadley and Medicine River Fields, respectively, are capped by widespread coals and fluvial sandstones (this study), suggesting the progradation northwards of a coastal plain immediately following deposition of the Glauconitic member. The coastal plain was dissected by a series of channel sequences with a general southeast to northwest orientation.

UPPER MANNVILLE DEPOSITION

The upper Mannville represents the dominance of regressive conditions, as a result of a phase of major clastic input and the relative lowering of sealevel. It consists of totally non-marine sediments in southern Alberta, nearshore marine sediments capped by non-marine sediments in central Alberta (Pembina, Athabasca, and Lloydminster areas) and by totally marine sediments in northern Alberta (Peace River area).

Upper Mannville sediments thicken markedly towards the northwest. The sequence is more than 420 metres thick in the Peace River area and thins to about 140 metres in an eastward and southward direction (Figure 12). The thickening trend in the Peace River area is a result of relatively rapid subsidence and subsequent infilling of marine sediments over the Peace River Arch (Cant, pers.comm.). A well defined depocentre or sub-basin (Figure 8) developed as a result of continued subsidence, which was named the Clearwater Shale sub-basin by

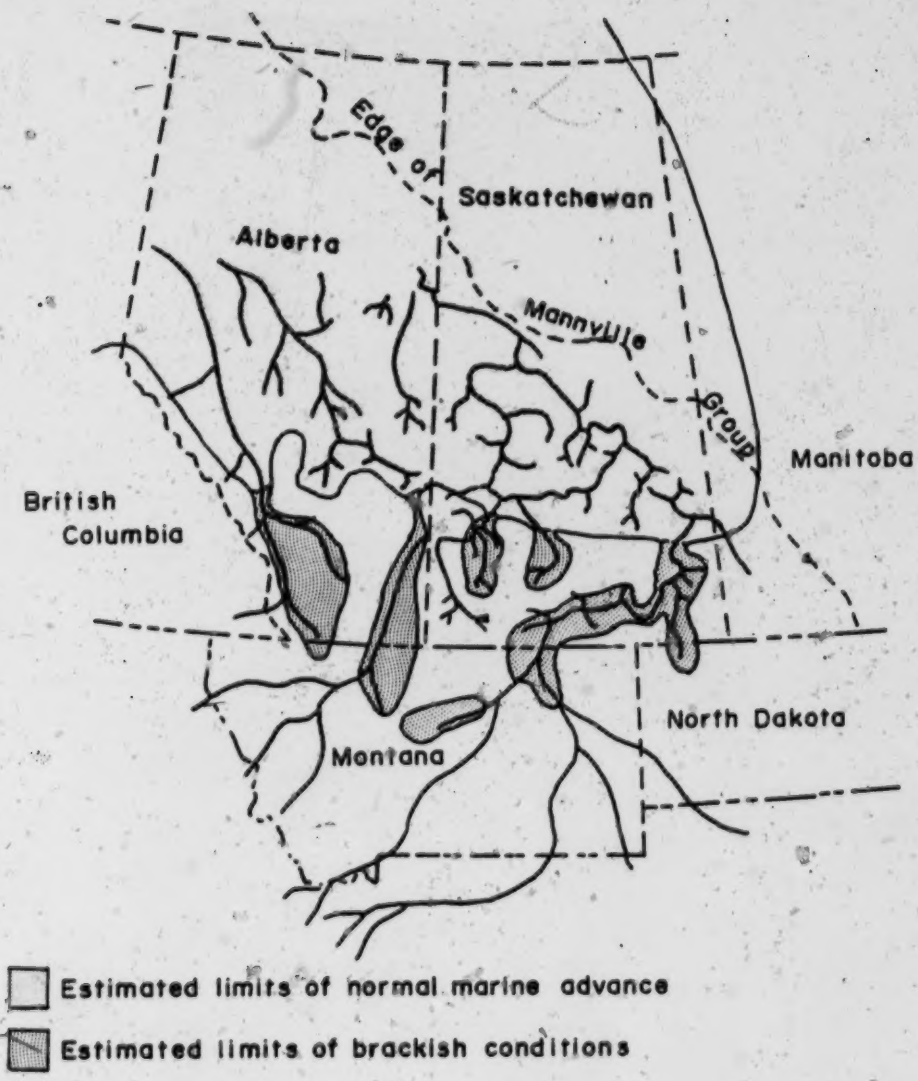


Figure 11. Speculated maximum marine advance during the early Albian. The boreal sea transgressed farthest up the drowned river valleys and low-lying areas (modified after Williams and Stelck, 1975; Christopher, 1980; McLean and Wall, 1981; and Singh, pers.comm.).

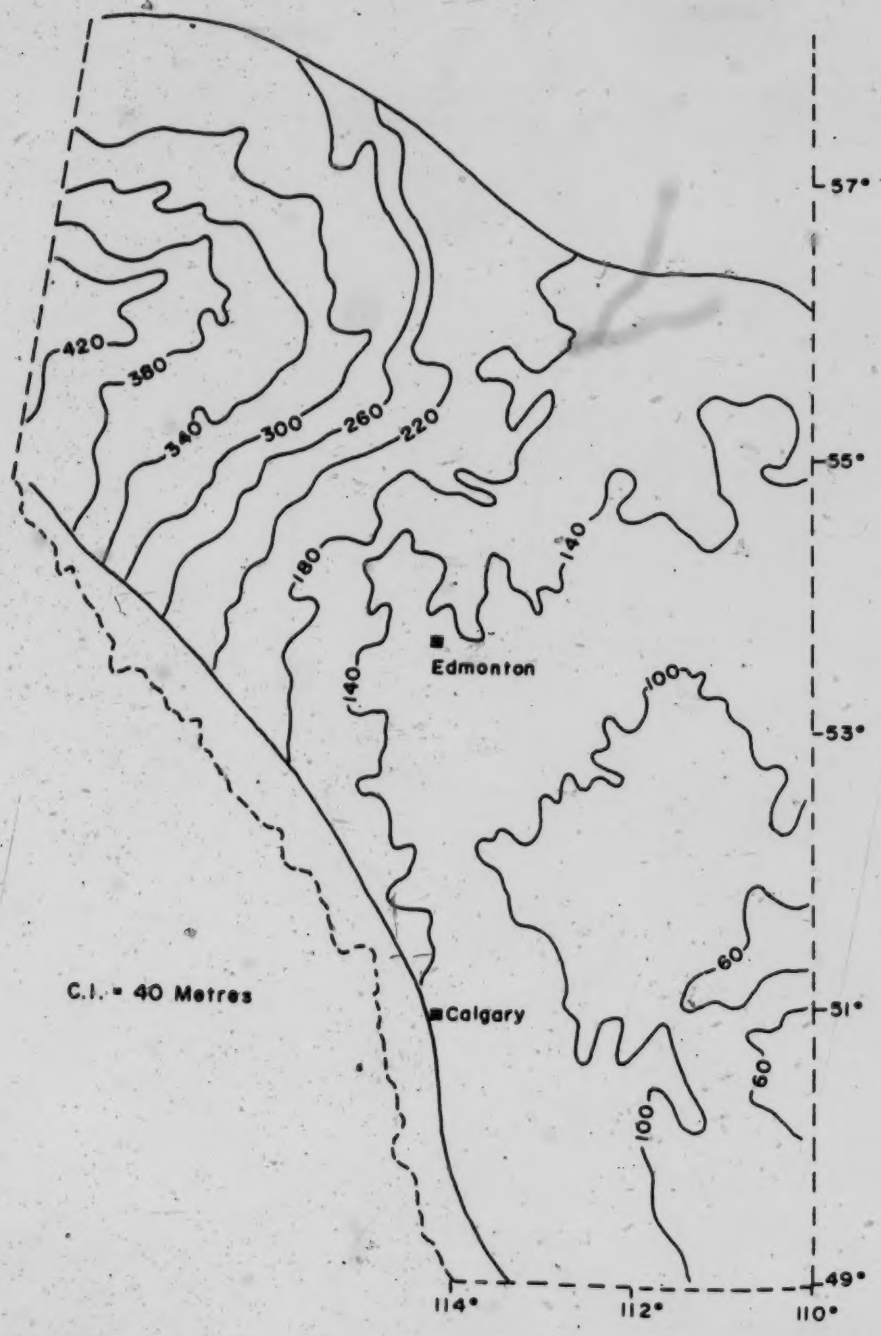


Figure 12. Isopach map of the middle and upper Mannville formations (Courtesy of Dr. D.J. Cant).

Jackson (1985). Relatively deep-water conditions prevailed within the sub-basin, but outside of the sub-basin relatively shallow-water conditions dominated. In the shallower areas in the west, a series of 10 to 50 metre thick transgressive-regressive cycles of the Falher Member developed (Cant, 1984). In the east, equivalent sequences were the McLaren, Waseca, Sparky, General Petroleum, Rex, and Lloydminster Formations.

In the Elmworth area, each of the five major transgressive-regressive cycles of the Falher Member consisted of beach sand and conglomerate sequences capped by coals. These sequences appeared to be locally deposited, probably due to the influences of the northern sub-basin. In east-central Alberta, the transgressions were more extensive, and repeatedly inundated as far south as the Lloydminster area. Marine shales associated with each transgressive pulse in this area were thin compared to equivalent shales in the north, but were laterally continuous over large areas. Coastal plain coals capping each transgressive-regressive cycle in the Elmworth area were commonly well preserved, but the coals overlying equivalent sequences in the Lloydminster area were usually thinner and not always preserved (Cant, in press; Wightman et al., in press).

A very extensive upper Mannville coal seam, referred to informally and locally as the Medicine River coal (this paper), proves the existence of a continuous coastal plain area in southern Alberta while areas to the north were undergoing marine deposition. This coal seam is elongate, trending southwest to northeast, and may reach thicknesses up to 8 metres (Strobl, 1983). In cross section L-L' (in pocket), the Medicine River coal is correlated over a distance of more than 100 km, from the Hoadley area northward to the Pembina area. The seam thins and splits towards the north, probably due to the increasing marine influence in that direction. A depositional hingeline (Figure 8) is drawn between a deep-water depositional setting of the northern sub-basin and the relatively shallow water-setting in the Pembina area (Jackson, 1985). The Medicine River coal was observed to pinch out south of this hingeline (this study).

TERMINATION OF MANNVILLE DEPOSITION

Mannville Group sedimentation was brought to an end by two major transgressions. A Middle Albian transgression, originating from the north, resulted in the deposition of the Harmon shale sequence. An Upper Albian transgression, originating from the south, resulted in the deposition of the Joli Fou shale sequence. These transgressions marked the beginning of the

extensive epeiric seaway that covered most of the interior of North America during the Upper Cretaceous (Williams and Stelck, 1975).

IV. MEDICINE RIVER FIELD SUBSTUDY

A total of 78 cores from the Medicine River Field and the surrounding area were examined and described in detail. The core logs are located in Appendix A. In addition, samples were examined for palynomorphs and dinoflagellates by Dr. C. Singh of the Alberta Research Council. Results are summarized in Appendix B. Trace fossils were identified from core photos by Dr. S.G. Pemberton of the University of Alberta. Trace fossil identification was an important asset for interpretation, and was especially helpful in sandy intervals which had poor recovery of palynomorphs and dinoflagellates.

In order to complete a reservoir study of the field, a computer database was generated using 216 wells in a 9 township area (850 sq.km). Blanking routines and digitizing techniques were required to produce the isopach and structure maps and the three-dimensional perspective diagrams. These maps and diagrams were used to describe sand thickness variation, structure on marker horizons, geometry of the reservoir units, and to explain the distribution of fluids within the Medicine River Field.

Four major lithologic units were identified. These were the Sheet Sands and Hoadley Bar lithosomes, and the post-Glauconitic coal and pre-Glauconitic coal channel sequences. Each unit represents a distinctive depositional setting and will be described individually. Figure 30 (in pocket) shows the distribution of each unit for a 60 township area.

The Sheet Sands and Hoadley Bar lithosomes were subdivided into a series of lithofacies. The term 'lithofacies' is a derivation of 'facies', defined by de Raaf et al (1965) as subdivisions distinguished by "lithological, structural, and organic aspects detectable in the field." In this study, the modifier "litho" denotes a facies defined primarily by the distinctive lithology. Further discussion of the term "facies" is presented in Walker (1984). Characteristic sedimentary structures and biogenic traces described for each lithofacies were used as aids to interpret the depositional environment.

A. SHEET SANDS LITHOSOME

The total thickness of the Sheet Sands lithosome is generally less than 15 metres (Figure 13). The vertical succession is consistent, beginning with offshore marine mudstones, passing upwards through lower shoreface interbedded mudstones, siltstones, and sandstones, to middle and upper shoreface amalgamated sandstones, to thin lagoonal mudstones, and terminating with the Glauconitic coal zone. Figures 14, 15, 16, and 17 show a typical cored interval with lithofacies boundaries marked by arrows.

MUDSTONE LITHOFACIES

The mudstone lithofacies is commonly massive in appearance, but displays low angle (0 to 5 degrees) planar lamination or wavy bedding wherever siltstone and sandstone interbeds are present. Load casts, slump structures and other soft sediment deformation features are associated with these interbeds. Bioturbation is recognized within some interbeds in the form of disturbed laminae and horizontal burrows. Locally deposited shell layers, 1 to 5 cm thick are minor sedimentary features.

Calcareous zones were identified, ranging from 15 to 60 cm thick. They are recognized in core as highly cemented zones displaying a vigorous reaction to dilute hydrochloric acid. On geophysical logs, these zones are detected by a sharp kick to the left on the natural gamma ray curve (towards 0 API units) and by a corresponding sharp kick to the right on sonic porosity and density porosity curves (towards 0% porosity). The deflection of the natural gamma ray curve towards 0 API units usually suggests a lithology change to a sandstone or limestone, but this is not always the case, as this example points out. These calcareous zones made excellent subsurface markers and appeared to be continuous from well to well in the study area. A calcareous zone in this lithofacies was labelled Marker 2 in the computer database and was used for correlation purposes in cross-sections.

INTERBEDDED MUDSTONE, SILTSTONE, AND SANDSTONE LITHOFACIES

Interbeds of mudstone, siltstone, and sandstone range from 0.5 cm to 10 cm in thickness, and are typically wavy bedded. The bedding is generally horizontal to low angle (0 to 5 degrees) with sharp lower contacts (Figure 18). Minor sedimentary features in this lithofacies include carbonaceous debris and laminations, and 1 to 10 cm thick shell layers. Pyritic and

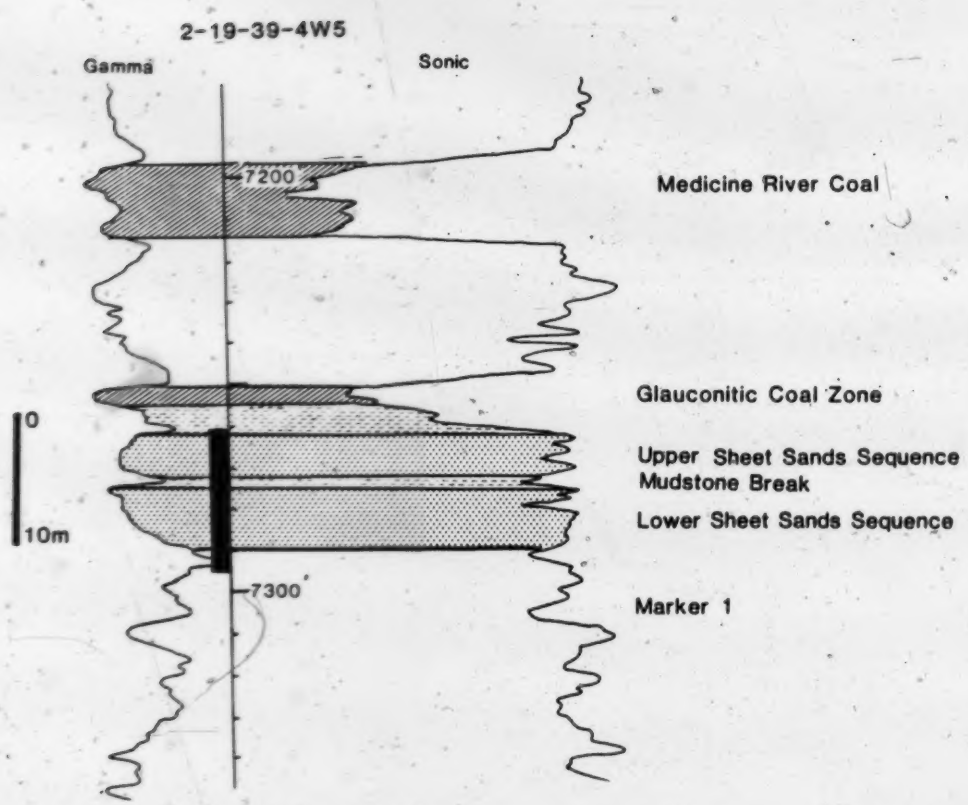


Figure 13. Typical Sheet Sands lithosome showing the major subdivisions for mapping purposes.

Figure 14. (photo 1 of 4).

Figure 15. (photo 2 of 4).

Typical cored interval of the Sheet Sands lithosome. Increasing depth corresponds to increasing "footage" marked on labels. Arrows indicate lithofacies boundaries. Box length is 75 cm.

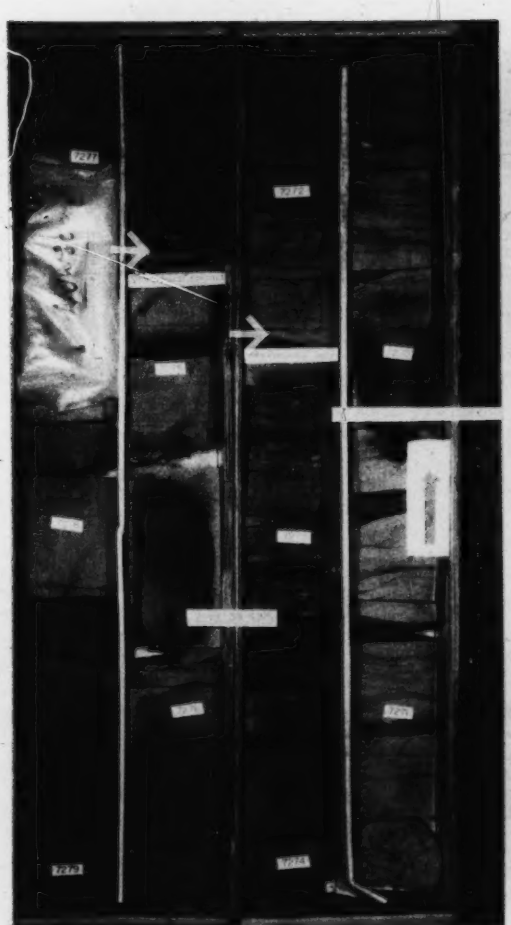


Figure 16. (photo 3 of 4).

Figure 17. (photo 4 of 4).

Typical cored interval of the Sheet Sands lithosome. Increasing depth corresponds to increasing "footage" marked on labels. Arrows indicate lithofacies boundaries. Box length is 75 cm.

sideritic concretions are randomly distributed throughout. Load casts, slump structures and other evidence of soft sediment deformation were sometimes observed along contacts between mudstone and overlying sandstone beds. This lithofacies is mildly bioturbated, and commonly has horizontal traces (such as *Planolites* sp. in Figure 18).

Some examples of planar and trough cross-bedded sandstones, up to 20cm thick, with sharp erosional bases were sometimes observed. These features are local in nature, possibly deposited during storm events. Finely laminated and rippled beds (Figure 19) are present in many intervals, reflecting relatively quiet water conditions.

Concretionary zones similar to those described in the marine mudstone lithofacies are also present in this lithofacies. A mapped calcareous zone, labelled Marker 1, was incorporated into the computer database, and was used for correlation purposes.

AMALGAMATED SANDSTONE LITHOFACIES

The amalgamated sandstones are of most interest because they are the main reservoir units in the Medicine River Field. They are subdivided into a lower and upper sequence separated by a 30 to 50 cm thick mudstone (See Figure 13). The lower sequence makes up the larger portion of the reservoir beds in the field.

Reichenbach (1981) described the sandstones of this lithofacies as moderately sorted, subangular to subrounded chert sublitharenites, after Folk's (1966) classification. In that study, quartz and chert made up the principal framework grains. Feldspars were present in minor amounts. Sedimentary and igneous rock fragments were also found to be minor constituents of these sandstones. Sedimentary rock fragments commonly consisted of subrounded shale or silty shale clasts. Igneous rock fragments consisted mostly of polycrystalline quartz, with minor microcline and plagioclase. Glauconite was a minor constituent.

Both the upper and lower sequences consist of amalgamated sandstone beds with sharp, often erosional, lower contacts. In some intervals, interbeds of mudstone and siltstone are present (Figure 20). The thickness of each bed ranges from less than 1 cm to more than 40 cm. The lateral persistence of each bed varies also, with the maximum extent commonly being less than 800 metres. Attempts to correlate beds from one cored interval to the next were not successful, even between wells that were 600 to 800 m apart.

Figure 18. Interbedded mudstones, siltstones, and sandstones showing wavy bedding and sharp lower contacts. Arrow indicates *Planolites* sp. Scale shown is 4 cm.

Figure 19. Ripple-laminated beds. Scale shown is 4 cm.

Figure 20. Amalgamated sandstone lithofacies showing the variation in grain size, structure, and thickness of beds. Note the sharp contacts between beds.

Figure 21. Amalgamated sandstone lithofacies showing crossbedding. Note the truncation surfaces along the base of each bed. Scale shown is 4 cm.

The grain size, bed thickness, and sedimentary and biogenic structures vary considerably between beds. Analyses available for most cores indicate significant variation of porosity and permeability between beds. A series of alternating oil-saturated and non-saturated zones is a result of the variation in permeability. Many of the non-saturated beds are argillaceous and commonly bioturbated (light grey units shown in Figure 20). Oil-saturated beds are commonly massive to faintly laminated, very fine grained to fine grained, well sorted sandstones (dark brown units shown in Figure 20). Low to moderate-angle, planar-tabular and trough crossbeds are common in this lithofacies, particularly in the lower sequence (Figure 21). Ripup clasts are sometimes present along the base of some crossbeds. Mud drapes and muddy laminae are common and appear to be deposited locally, perhaps infilling depressions during quiet water periods. Sharply truncated bioturbated tops (Figure 22) present in some intervals may be indicative of alternating rapid and slow depositional rates (Ekdale *et al*, 1984). During periods of relatively slow sedimentation, upper portions of beds become extensively bioturbated. During periods of relatively rapid sedimentation, the underlying bioturbated beds are truncated and buried by overlying beds deposited too quickly to become bioturbated.

Minor carbonaceous debris and laminations are present throughout this lithofacies. Pyritic and sideritic concretions, minor shell fragments and 1 to 10 cm thick shell layers are present. Load casts, slump structures, contorted beds and other evidence of soft sediment deformation are common along contacts between mudstone and overlying sandstone beds.

Trace fossils identified in the amalgamated sandstone lithofacies include *Planolites* sp., *Skolithos* sp., *Arenicolites* sp., *Bergaueria* sp., and *Asterosoma* sp. This diversity suggests a shallow marine depositional setting. Of particular interest, however, are the screw-shaped traces (possibly *Gyrolithes* sp.) associated with synaeresis cracks (Figure 23). These latter features may be brackish-water indicators (Wightman *et al*, in press), resulting from fresh-water mixing.

CARBONACEOUS MUDSTONE LITHOFACIES

The carbonaceous mudstone lithofacies consists of black, commonly massive, mudstones with minor sandstone and siltstone interbeds. Bioturbation features associated with sandstone interbeds, such as *Planolites* sp. (Figure 24), suggest some periods of marine influence. Coaly and carbonaceous laminations in this lithofacies indicate considerable input of

organic material. A buff coloured argillaceous limestone, up to 30 cm thick, is present in some cores, but this lithology is local in nature.

Significant destruction of sedimentary structures by rooting, originating from the Glaucontic coal zone, caused a massive appearance in many intervals.

COALY LITHOFACIES

Argillaceous coals and some clean coals of this lithofacies make up the Glauconitic coal zone. This zone covers both the Sheet Sands lithosome and the Hoadley Bar lithosome, making an excellent datum for correlation between the twQ. Progradation of an extensive coastal plain and the development of an elongate peat swamp resulted in the formation of this coal zone.

SHEET SANDS LITHOSOME INTERPRETATION

The sheet sandstones examined in the Medicine River Field represent a small portion of an extensive southwest to northeast oriented, prograding shoreline. The sequence shallows upward from offshore marine sediments (mudstone lithofacies) to shoreface sediments (interbedded mudstone, siltstone, and sandstone lithofacies and amalgamated sandstone lithofacies) to lagoonal sediments (carbonaceous mudstone lithofacies) to swamp deposits (coaly lithofacies), indicating overall progradation of a shoreline.

The amalgamated sandstone lithofacies closely resembles sheet sandstones described by Goldring and Bridges (1973). In that study the sheet sandstone sequences consisted of amalgamated sandstone beds that were commonly 5 to 70 cm thick, but some were 2 m or more, separated by interbeds of mudstones; or as visually amalgamated sandstone beds with little or no fine sediment in between (Figure 25). Lateral persistence of beds in that study ranged from a few metres to several kilometres. Typically, the main part of each bed was a fine to very fine grained, well sorted sandstone. Some sandstone tops were gradational but many showed penecontemporaneous erosion. Sequences with bioturbated tops and penecontemporaneous erosion (diagram B in Figure 25) appear to be similar to the truncated bioturbated tops described for the amalgamated sandstone lithofacies in the Medicine River Field.

Given the similarities, such as the limited lateral continuity, the presence of bioturbated tops with penecontemporaneous erosion, and variation in bed thickness of the amalgamated

Figure 22. Amalgamated sandstone lithofacies showing truncated bioturbated tops.

Figure 23. Amalgamated sandstone lithofacies showing synaeresis cracks (small arrows) associated with screw shaped traces (*Gyrolithes* sp., large arrows). Scale shown is 4 cm.

Figure 24. Lagoonal carbonaceous mudstones with sandstone and siltstone interbeds. Arrow indicates *Planolites* sp. Scale shown is 4 cm.

sandstone sequences, the writer considers the amalgamated sandstone lithofacies to resemble the shoreline associated amalgamated beds described by Goldring and Bridges (1973).

Considerable variation in the thickness of the upper and lower sheet sands sequences (Figure 13) and the variation in grain size, structures, and the thickness of beds indicate local deposition. The presence of *Muderongia* sp., synaeresis cracks, screw-shaped trace fossils (*Gyrolithes* sp.) and pyritic and sideritic concretions indicate that brackish-water conditions were prevalent during sheet sands deposition.

The vertical succession created by a prograding shoreline can be related to progressive depth and process changes. Numerous fluctuations of the shoreline likely occurred, depending upon sealevels, variation in sediment supply and subsidence. The shallowing-upward trend, however, indicates overall regressive conditions.

A comprehensive review by Heward (1981) suggests that many regressive sheet sands sequences are the result of relatively high sediment supply and rapid rates of progradation. Their large sand volumes imply sediment supply from rivers with wave-dominated deltas and strandplains (Heward, 1981). No well defined limits to a delta could be drawn in the Medicine River Field, but a series of marine-reworked, deltaic sandbodies are considered the source for the sheet sandstones there. This interpretation accounts for the variation in the thickness, grain size and structures in beds, the localized thickness trends of the sequence, and for the brackish-water indicators observed. Redistribution of these sediments likely occurred when delta lobes were abandoned, and during storm events. A possible modern analogue is shown in Figure 26. A wave-dominated delta was chosen because of the association with extensive barrier island sandstones of the Hoadley Bar lithosome located immediately north of the Medicine River Field.

B. HOADLEY BAR LITHOSOME

The total thickness of the Hoadley Bar lithosome is 20 to 35 metres (Figure 27). It has a consistent vertical succession beginning with massive marine mudstones, passing upwards through offshore to lower shoreface interbedded mudstones, siltstones, and sandstones, to middle and upper shoreface massive to low-angle laminated sandstones and terminating with the Glauconitic coal zone. In some localities, lagoonal carbonaceous mudstones are present between the shoreface sandstones and the coal zone. The main difference between the Sheet

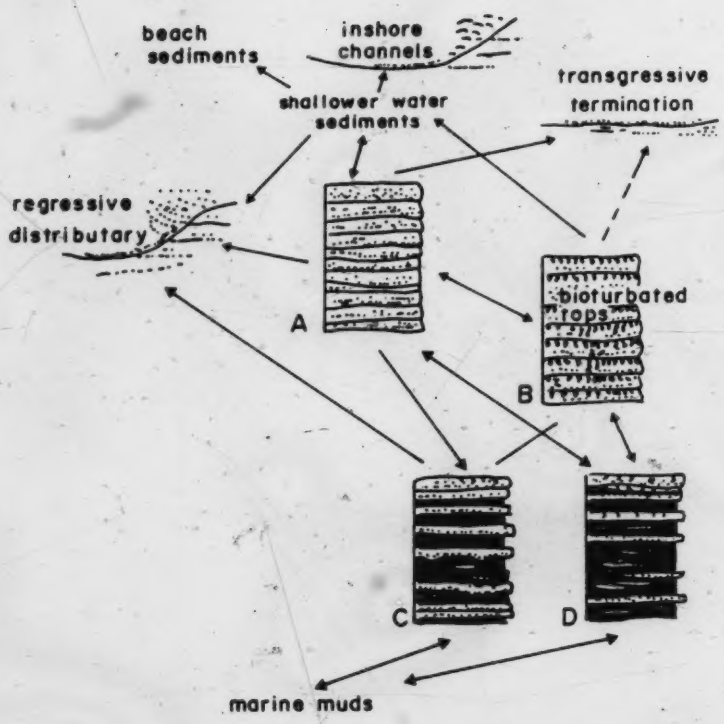


Figure 25. Shoreline-associated sheet sandstone sequences observed from ancient analogues (after Goldring and Bridges, 1973).

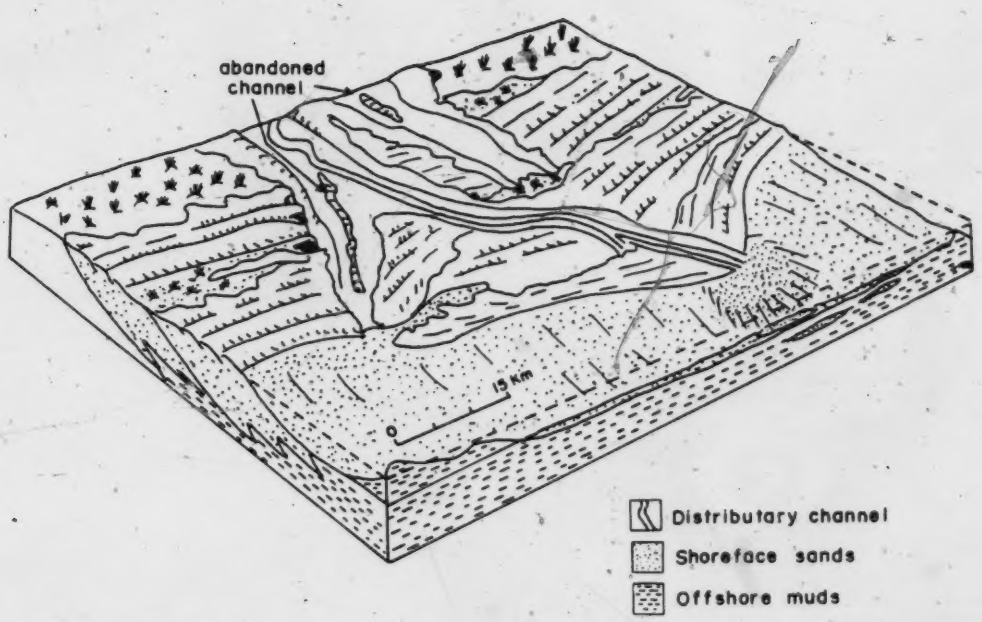


Figure 26. Schematic sketch of a wave-dominated delta (after Weise, 1980).

Sands lithosome and the Hoadley Bar lithosome is that the main sand body of the latter is made up of thicker, more continuous and highly reworked sandstones deposited in a relatively high energy shoreface environment.

MUDSTONE LITHOFACIES

This lithofacies is very similar to that described in the Sheet Sands lithosome. The calcareous zones present in the Medicine River Field appear to continue over large portions of the Hoadley Bar lithosome.

Northward of the Hoadley Bar lithosome, based on geophysical logs, these marine mudstones appear to be seaward equivalents of the bar sandstones. These mudstones may correlate to the Clearwater Formation. They are about half the thickness of the bar sandstones, due in part to differential compaction.

INTERBEDDED MUDSTONE, SILTSTONE, AND SANDSTONE LITHOFACIES

The interbedded mudstone, siltstone, and sandstone lithofacies is similar to that described in the Sheet Sands lithosome. A major difference is the introduction of much thicker interbeds of fine to medium grained sandstones. Soft sediment deformation features appear to be more prominent as a result of loading by these interbeds (Figure 28). Bioturbation structures are generally confined to this lithofacies.

A prominent calcareous marker (Marker 1) of this lithofacies, also identified in the Sheet Sands lithosome, is correlated across the Hoadley Bar lithosome.

MASSIVE TO LOW-ANGLE LAMINATED SANDSTONE LITHOFACIES

This lithofacies is characterized by relatively continuous and uninterrupted, fine grained to medium grained sandstones, commonly with low-angle (0 to 10 degrees) laminated or massive beds. Little or no bioturbation is recognized, few mudstone interbeds are present, and only minor carbonaceous debris and laminations break up this sandstone sequence (Figure 29). Low-angle planar and trough cross-bedding appear to be the dominant sedimentary structures in this lithofacies. Minor mudstone drapes are associated with some trough crossbeds. Chert and quartzite pebble layers are minor features and are generally less than 1 cm thick. There is a gradational contact between this lithofacies and the underlying interbedded mudstone, siltstone,

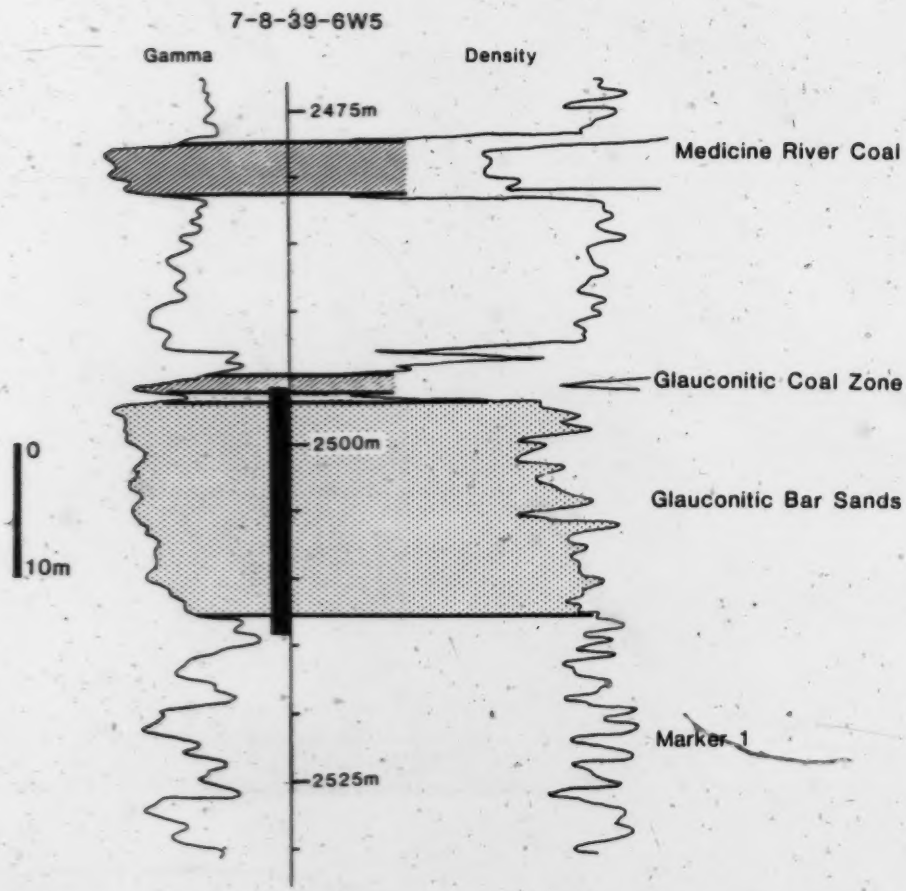


Figure 27. Typical Hoadley Bar lithosome showing the major subdivisions for mapping purposes.

and sandstone lithofacies. Thickness of the massive to low-angle laminated sandstone lithofacies ranges from 10 to 25 metres, and is the main reservoir unit in the Hoadley and Ferrier gas fields.

Dawson (1982) described the sandstones of this lithofacies as well sorted, medium grained sublitharenites to fine grained chert arenites after Folk's (1966) classification. In that study, quartz and chert made up the principal framework grains. Minor amounts of metamorphic and volcanic rock fragments made up the lithic grains. Detrital glauconite was a minor constituent.

CARBONACEOUS MUDSTONE LITHOFACIES

This lithofacies is present in some sequences of the Hoadley Bar lithosome and is very similar to descriptions given for the carbonaceous mudstone lithofacies in the Sheet Sands lithosome. In the Hoadley Bar lithosome, however, these mudstones are thinner and bioturbation structures are not as prevalent. Destruction of sedimentary structures by rooting is common.

COALY LITHOFACIES

Most commonly, this lithofacies lies directly on the the massive to low-angle laminated sandstone lithofacies. Perhaps the lack of lagoonal mudstones is indicative of emergence of the bar sequence as sea level lowered and the coastal plain prograded seaward. The Glauconitic coal zone is not present north of the Hoadley Bar lithosome (See cross section L-L' in pocket). Coals are best developed landward, in a distal position from marine influences.

HOADLEY BAR LITHOSOME INTERPRETATION

The linear geometry of the Hoadley Bar lithosome (Figure 30), the succession of lithofacies observed, and the shallowing-upward trend suggest a regressive barrier island system. A schematic sketch of the proposed depositional setting is given in Figure 31.

There is a well defined boundary between the Sheet Sands lithosome and the Hoadley Bar lithosome (Figure 30). An interpretation favoured in this study, which accounts for the sharp boundary, is that the Hoadley Bar lithosome resulted from a change in depositional conditions, and likely formed after deposition of the Sheet Sands lithosome. The Hoadley Bar

Figure 28. Interbedded mudstone, siltstone, and sandstone lithofacies in the Hoadley Bar lithosome. Scale shown is 4 cm.

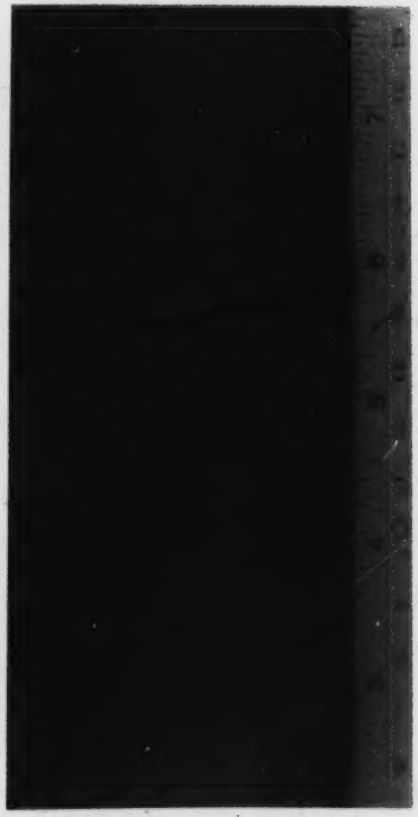


Figure 29. Massive to low-angle laminated sandstone lithofacies in the Hoadley Bar lithosome. Scale shown is 14 cm.

lithosome developed relatively thick, marine-reworked, shoreface sandstones during a stillstand, when rates of sedimentation and subsidence were in equilibrium. Some of the sheet sandstones of the Sheet Sands lithosome, that may have occupied a more seaward position prior to stillstand conditions, were reworked or winnowed. Lagoonal mudstones accumulated in a back-barrier setting as the barrier prograded seaward.

An alternative interpretation, suggested by other researchers in the study area, may also account for the sharp boundary between the Sheet Sands and Hoadley Bar lithosomes. In this interpretation, the sheet sandstones formed as a delta, building out and infilling a large lagoon created by the barrier. A modern example cited is the Colorado Delta, located along the Texas Gulf coast. This interpretation is not favoured by the writer. Results of regional mapping (this paper) indicate that the Sheet Sands lithosome is dominantly sandy over a length of at least 150 km and a width of 50 km. The Colorado Delta is infilling a lagoon only 10 km wide with muddy sediment. Kanes (1970) uses the Colorado Delta as an example of a typical "mud" delta, forming into a body of water in which there is little reworking or transport of sediment. Lower energy levels are usually associated with a lagoonal setting, as this example points out. In areas where energy levels are higher with respect to sediment supply, such as a wave-dominated delta, extensive reworking and transport of sediment may take place resulting in a "sand" delta (Kanes, 1970). The writer finds that the possibility of considerable reworking and transport of sediment, which would be required to produce an extensive sandy sequence, is unlikely to occur in a lagoonal setting.

Chiang (1985) considers conglomeratic beach deposits within the Hoadley Bar lithosome to originate from rivers in the southwest, supplying chert and quartzite pebbles to the shoreline. Strong longshore currents transported these pebbles farther along the bar trend. No pebble or cobble sized sediments were identified from the Medicine River Field or adjacent strata, so the conglomerates within the Hoadley Bar lithosome were probably not derived from a direct southerly source. An as yet unmapped source to the west may have been a major supplier of sediment. The thickening of these conglomerates, and increase in average pebble size towards the southwest, also indicate that an important southwesterly source was present during formation of the barrier sandstones (Strobl, 1984).

The Hoadley Bar lithosome extends from the Foothills in the southwest to Edmonton in the northeast (Figure 30). A shoreline trend of this magnitude (200 km long by 25 km wide)

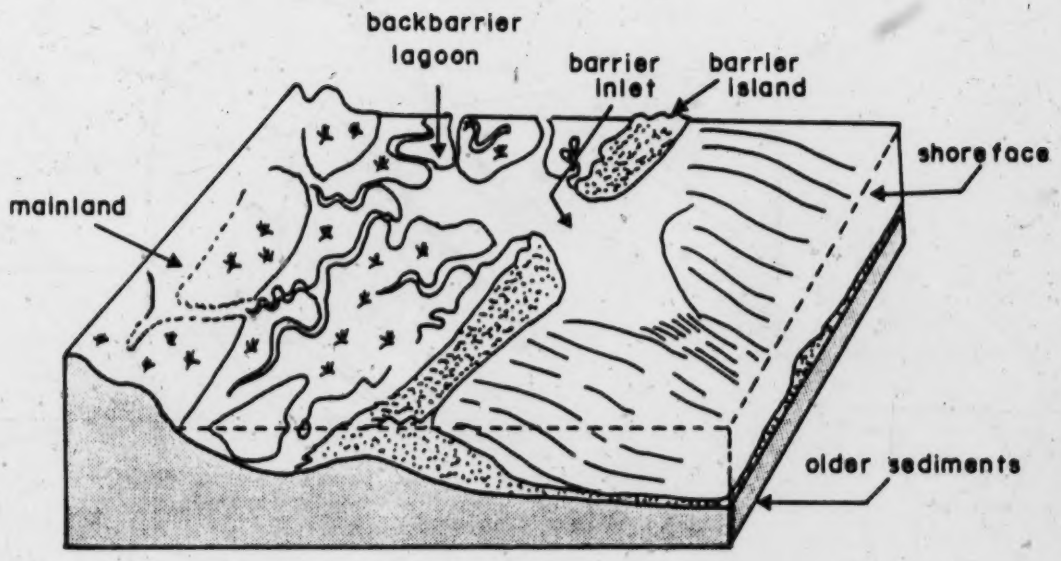


Figure 31. Schematic sketch of a barrier island system (after Oertel, 1985).

supports the idea that a shoreline of similar scale was present during deposition of the Sheet Sands lithosome.

C. POST-GLAUCONITIC COAL CHANNELLING EPISODE

Sequences of this episode consist of 20 to 35 metres of muddy, and lesser amounts of sandy infill (Figure 32). Dinoflagellates recovered from several intervals have shown a predominance of *Muderongia* sp., indicative of a brackish depositional environment (Singh, pers.comm.). In core, the sequence is most commonly a massive, black mudstone, with minor sideritic and pyritic concretions throughout. Minor sandstone and siltstone interbeds within these mudstones were highly disturbed, possibly due to bioturbation. Carbonaceous debris and laminae are common throughout the sequence. No core was available for the sandy-infilled sequence of this channelling episode. Based on geophysical logs, many of the sandy sequences appear to fine upwards in grain size, and have abrupt bases and gradational tops. In some instances, thick sandstones appear to form a basal lag in sequences dominated by muddy infill. Sandy sequences are commonly deposited close to muddy sequences (See cross section A-A', in pocket).

Because of exceptional well control in the Medicine River Field area, the sequence was mapped with enough detail to determine maximum widths and depths of channelling, in addition to locating major meander belts, for a distance of more than 60 km. The sequence trends southeast to northwest, unconformably cutting the Sheet Sands and the Hoadley Bar lithosomes (Figure 30). The Glauconitic coal zone is not present in any of 62 wells containing this sequence. Although it is possible that an open channelway may have prevented accumulation of peats (forming the Glauconitic coal zone) immediatedly overlying this sequence, it seems more likely that the peats were eroded. Note the sharp and disconformable contact between the channelled interval and the earlier deposited sheet sandstones and bar sandstones (Cross sections A-A', B-B', C-C', D-D', G-G', H-H' and I-I', in pocket). If peats were being deposited during this channelling episode, a transition from relatively clean coals, distal from this sequence, to argillaceous coals or carbonaceous mudstones, proximal to this sequence, would be expected. Peats formed in areas close to active clastic deposition are likely to form carbonaceous shales, or at best high ash coals (McCabe, 1984). Evidence from the Medicine River Field area indicates that relatively clean coals are present proximal to areas

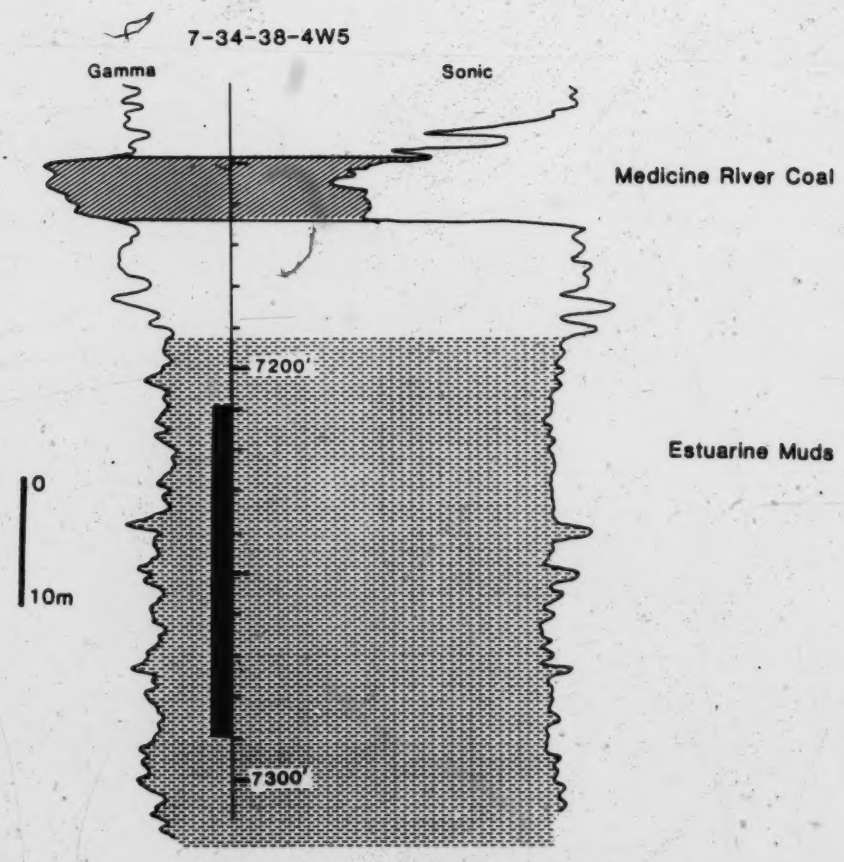


Figure 32. Typical post-Glauconitic coal channel sequence. Note that the Glauconitic coal zone, normally 15 to 30 metres below the Medicine River coal, is absent

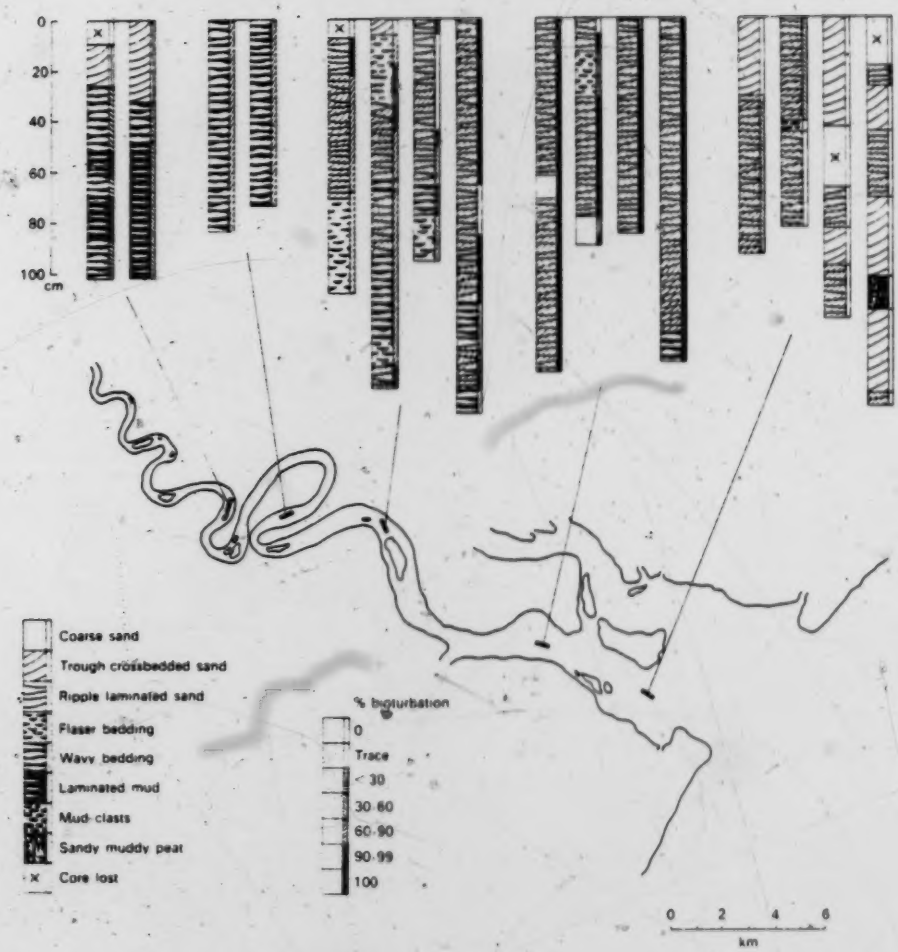


Figure 33. Schematic sketch of a modern estuary showing variable lithologies of point bars (modified from Howard *et al*, 1975).

of channelling. In addition, the tops of some sequences are located close to the Medicine River coal (Cross sections D-D', G-G', and H-H', in pocket), suggesting that this sequence was formed after deposition of the Glauconitic coal zone and after deposition of 15 metres or more of its overlying sediments.

Given the geometry and extent of channelling, and the marine indicators, an estuarine environment of deposition is proposed (Figure 33). Modern riverine-estuaries may display a change from sandy to muddy infilling, particularly in zones of freshwater mixing. Daily and seasonal changes in fluvial and tidal current strength cause the zone of mixing to migrate upstream and downstream resulting in deposition of muds over tens of kilometres of channel length (Rahmani, 1986). The estuarine interpretation for this channel sequence is supported by Rahmani (pers.comm.) but is opposed by an abandoned fluvial channel interpretation given by Chiang (1985).

Three other channel sequences, dominated by muddy-infilling, in which the Glauconitic coal zone was not present were recognized in the Hoadley Bar lithosome (Figure 30). Fewer data points were available to map these sequences, but the similarities to the well mapped sequence in the Medicine River Field indicate that they may be estuarine also. Cross section I-I' (in pocket) shows the disconformable nature, and the similarities to the channel sequence in the Medicine River Field. These are not considered to be tidal channels because channelling likely occurred after deposition of the Glauconitic coal zone and after deposition of 10 metres or more of its overlying sediments. This interpretation suggests that these are late channelling episodes formed during or after deposition of coastal plain sediments. A tidal channel interpretation implies that channelling occurred during deposition of the barrier sandstones.

D. PRE-GLAUCONITIC COAL CHANNELLING EPISODE

This sequence is one of predominantly sand-infilling and has a variable orientation of channels. It can be distinguished from the younger channel sequence by the presence of the Glauconitic coal zone (Figure 34). In some localities, this sequence is only partially preserved, and appears to be truncated by the younger channel sequence. An example of this is in Township 38, Range 4 in Figure 30. Cross sections through this sequence (E-E', F-F', and J-J', in pocket) show the disconformable nature and the variable thicknesses and widths of channelling. The sequence may be 30 metres or more thick, suggesting that much of the

sandy-infill is amalgamated.

In core, this sequence has a fining-upward trend, with medium to fine grained sandstones at the base to very fine grained sandstones, siltstones and mudstones towards the top. Carbonaceous mudstones (possibly lagoonal) and a thin Glauconitic coal zone, cap the sequence. The sandstones are commonly massive in appearance, but low- to moderate-angle crossbeds (5 to 15 degrees), often containing ripup clasts, are observed, particularly towards the bases. Carbonaceous debris and pyritic concretions are randomly distributed throughout. Destruction of sedimentary structures by rooting is common towards the top. Rooting probably originated from the Glauconitic coal zone.

The channel sandstones of this episode are considered by Reichenbach (1981), to have a similar mineralogy as the amalgamated sandstone lithofacies described for the Sheet Sands lithosome. They were described as chert sublitharenites after Folk's (1966) classification. Major differences were that no glauconite grains were observed, and that the heavy minerals were not concentrated into layers as they were in the Sheet Sands lithosome.

The presence of the Glauconitic coal zone in the sequence is an important consideration in determining the time of channelling. Chiang (1985) suggests that the sequence may represent distributary channels supplying sediments to the sheet sandstones in the Medicine River Field. Another possibility is that this sequence is estuarine in nature, occurring after deposition of the sheet sandstones but before deposition of peats (forming the Glauconitic coal zone). Some bioturbated beds and horizontal and vertical burrows observed in core (14-28-36-5W5 and 8-30-36-5W5 of Appendix A) indicate a marine influence during deposition of this channelling episode. Channel sequences of the same age, located to the northeast of the Medicine River Field, display moderate bioturbation and contain tidal bundles and mud couplets (Rahmani, pers.comm.). These observations also indicate a marine influence during deposition, and support an estuarine interpretation.

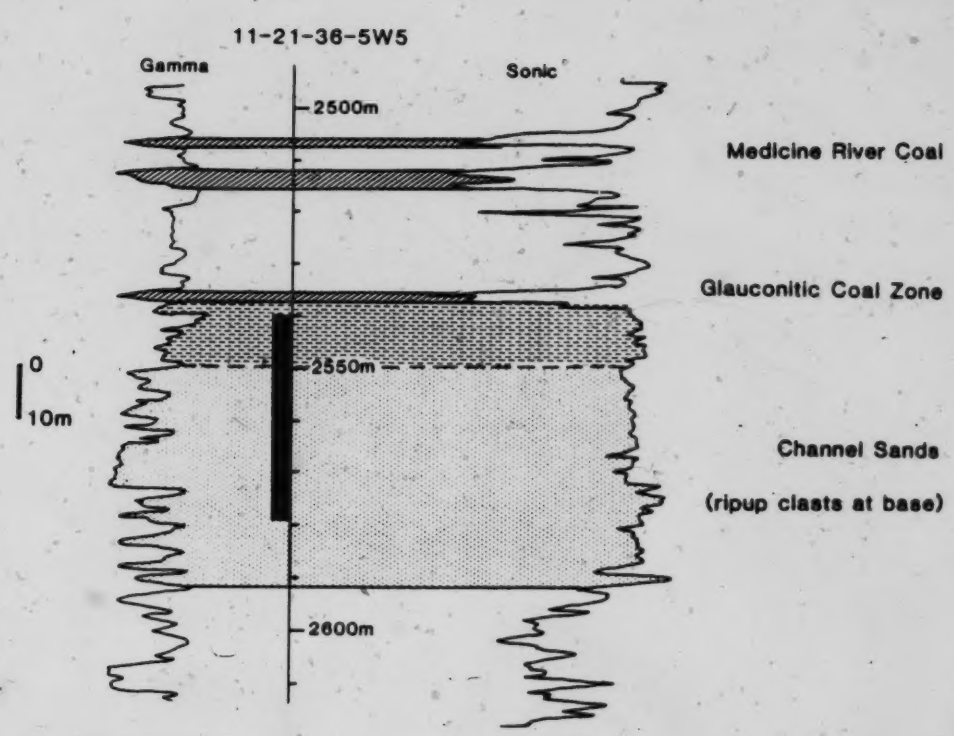


Figure 34. Typical pre-Glauconitic coal channel sequence. Note that the Glauconitic coal zone is present.

E. RESERVOIR STUDY

The Medicine River oil field was discovered in 1965 and produced oil until the late 1970's. Average daily production per capable well in 1965 was 29 bbl of oil per day (or 4.6 m^3). Estimates made in 1966 for oil in place and for oil recoverable were 95,040,000 bbl (or approximately 15,111,000 m^3) and 11,140,000 bbl (or approximately 1,771,000 m^3) respectively (Watkins, 1966). In 1975, however, cumulative oil production was only 3.8 million bbl (or approximately 604,000 m^3) which is significantly less than that predicted in 1966 (ERCB, 1983). Oil production declined significantly after 1975.

Oils produced in the Medicine River Field varied from 26 deg. API to 41 deg. API (Watkins, 1966). The reservoir had an anomalously high initial pressure in the order of 3800 psi, combined with producing gas/oil ratio variations related to structure (Watkins, 1966).

Static borehole pressure declined significantly after 1971, at which time secondary recovery was initiated with water injection. After 1974, average gas/oil ratios in the oil pool climbed to 3,000 ft^3/bbl. marking the beginning of declining oil production. Gas production from the gas cap was allowed to increase dramatically in 1981, resulting in average daily gas production to increase from 30,000 m^3 to more than 200,000 m^3 after 1981. Water production in the oil pool jumped from 0 m^3 prior to 1978 to more than 60 m^3 metres in 1983. With declining oil production, increasing gas/oil ratios, increasing water produced and declining static borehole pressure after 1981, the field was becoming more and more uneconomic. Approximately 4% of the estimated oil in place was recovered from the main oil pool, based on calculations by the author and from published cumulative oil figures by the ERCB (1983).

Each producing well was perforated, acid washed and fractured. The pay zone was an average of 3.5m thick, reaching a maximum of about 6m (Watkins, 1966). The number of producing wells ranged from 20 in 1966 to 45 in 1974. Water injection was implemented in 1971 (ERCB, 1983).

The main reservoir unit of the Medicine River Field consisted of the more porous and permeable portions of the Sheet Sands lithosome described earlier in the core study. The sheet sandstones of this lithosome offered a widespread reservoir unit throughout the area. In the main pool (Figure 35), light gravity oils and an associated gas cap were trapped updip by mudstones of a sinuous channel sequence. An auxiliary pool, located to the northwest, appeared to be trapped updip by relatively impermeable sheet sandstones. The permeability

reduction may have been caused by diagenetic effects and/or changes in lithology. Extreme variation in porosity and permeability, porosity-reducing diagenetic problems, and the limited lateral persistence of pay zones within these sheet sandstones were recognized obstacles for explorationists in this area. Dry wells or wells that produced for only short periods were commonly located close to actively producing wells.

The prospect for more oil pools like those in the Medicine River Field appear to be good. Many of the recent discovery wells, however, have been short-lived. Many of these newer discoveries produced oil and associated gas with a high initial pressure but later proved to be uneconomic even after fracturing and acidizing. Perhaps the next major discovery on the scale of the Medicine River Field will be associated with updip trapping by another mud-filled channel system. It is already known that mud-filled channel sequences are the main trapping mechanisms in the Ferrier and Hoadley gas fields. Each muddy sequence divides the barrier reservoir sandstones into separated reservoir compartments and serves as an updip seal for hydrocarbons (Chiang, 1985). Three proposed channel sequences shown in Figure 30 (located west of the Medicine River Field) are examples of the traps described by Chiang (1985). Exploration for hydrocarbons in this area has focused around the discovery and delineation of these mud-filled channel sequences because of their importance as traps.

STRUCTURE AND GEOMETRY OF THE RESERVOIR UNITS

The structural trends of the reservoir sandstones are relatively simple, dipping at approximately 12 metres per kilometre towards the west-southwest. In Figure 36 the top of the sheet sandstones in the Medicine River Field and the downcutting by the channel sequence are shown. The irregular structural bumps in the centre portion of the diagram may be the result of differential compaction. Surrounding areas that appear to have a smoother surface were contoured with fewer data points. If more data points were available in these areas, structural bumps would likely be present similar to those observed in the centre portion.

Structural trends on every datum are very similar. Upper datum horizons such as the top of the Medicine River coal and the top of the Glauconitic coal (Figures 37 and 38 respectively), are virtually mirror images of lower ones such as the top of Marker 1 and the top of Marker 2 (Figures 39 and 40 respectively). Because of these similarities, the structural trends observed are considered to be post-depositional, resulting largely from the regional loading

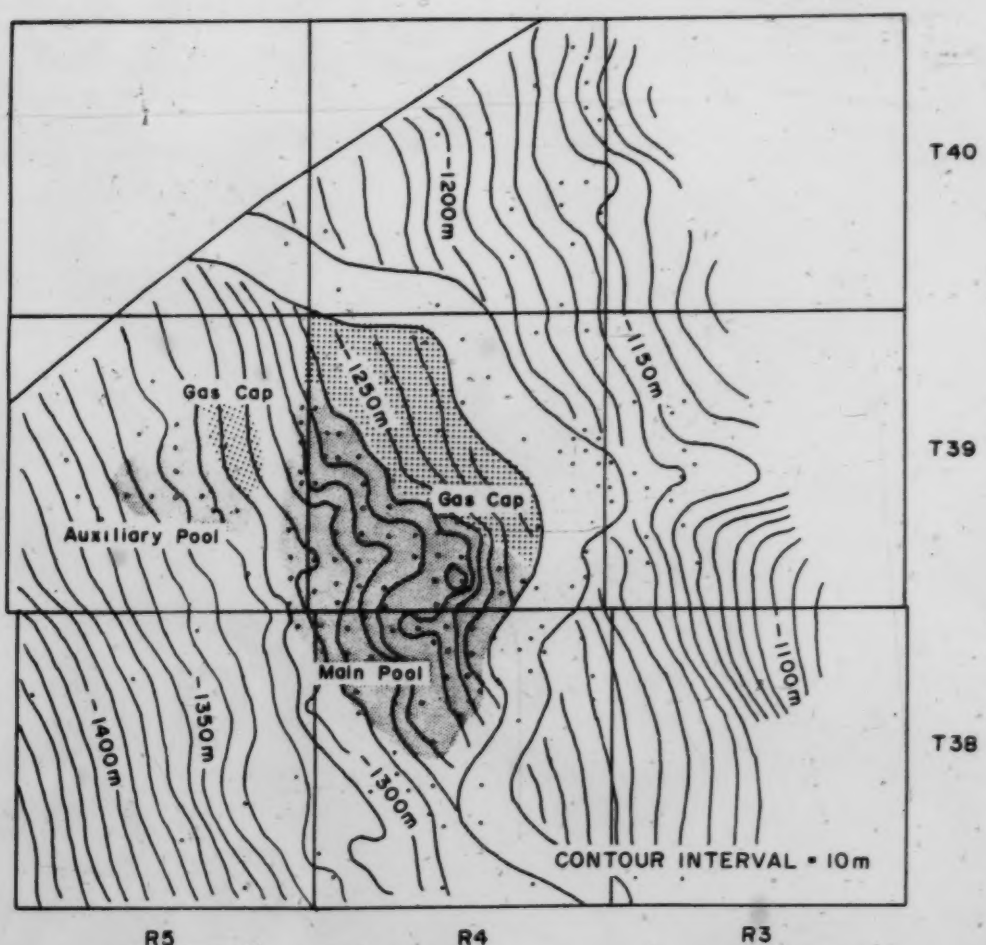


Figure 35. Structure map of the top of the sheet sandstones in the Medicine River Field. The main oil pool and auxiliary oil pool are shown with their respective gas caps.

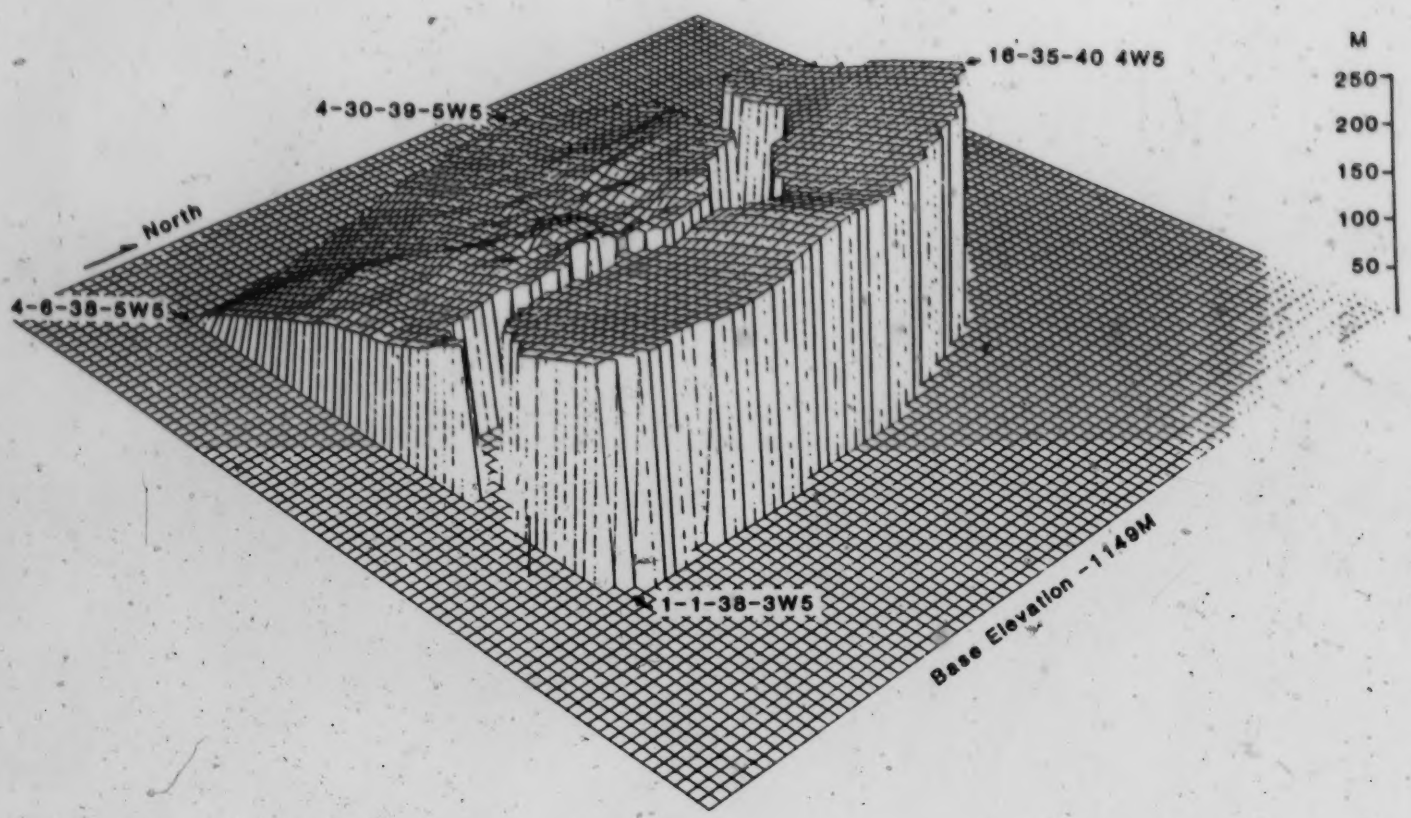


Figure 36. Perspective diagram of the Medicine River Field viewed from the southeast. The top of the sheet sandstones and the down-cutting by the post-Glauconitic coal channel sequence are shown.

effects of the Columbian and Laramide Orogenies in the west. Irregularities of the contour lines in these figures are likely the result of differential compaction between sandstones and mudstones in the interval from the pre-Mannville unconformity to the Glauconitic member.

The position of the main oil pool of the Medicine River Field is attributed to the shape and position of the post-Glauconitic coal channel sequence (Figure 35). The main pool appears to be trapped within a large meander of this sequence.

On a smaller scale, Watkins (1966) suggested that extreme variation in gas/oil ratios between wells, (290 ft^3/bbl to 5,000 ft^3/bbl) may be related to local structural variation. The bumps in Figure 36 and irregularities of contour lines in Figures 37, 38, 39 and 40 may be examples of local structures suggested by Watkins.

SAND THICKNESS VARIATION

The thickness variations of the lower and upper sandstone units (See Figure 13) are shown in Figures 41 and 42, respectively. The lower sandstone unit comprises the bulk of the total sandstones present in the Medicine River Field, and is the most important producing zone. The lower sandstone unit varies from 2.5m to more than 8.0m thick and generally has southwest to northeast thickness trends, possibly due to marine reworking. The upper sandstone unit varies from 0.5m to 5.0m with similar southwest to northeast thickness trends. Both the upper and lower sandstone units are truncated by the post-Glauconitic coal channel sequence. An isopach map of the interval from the top of the upper sandstone to the base of the lower sandstone (Figure 43) is shown for comparison purposes. The variation in thickness of the sheet sandstones (Figure 43) over relatively short distances suggests localized deposition. Observations from the core study indicate that the beds within each sandstone unit have small lateral extent, also indicative of localized deposition. This evidence supports a deltaic interpretation for the sheet sandstones in the Medicine River Field.

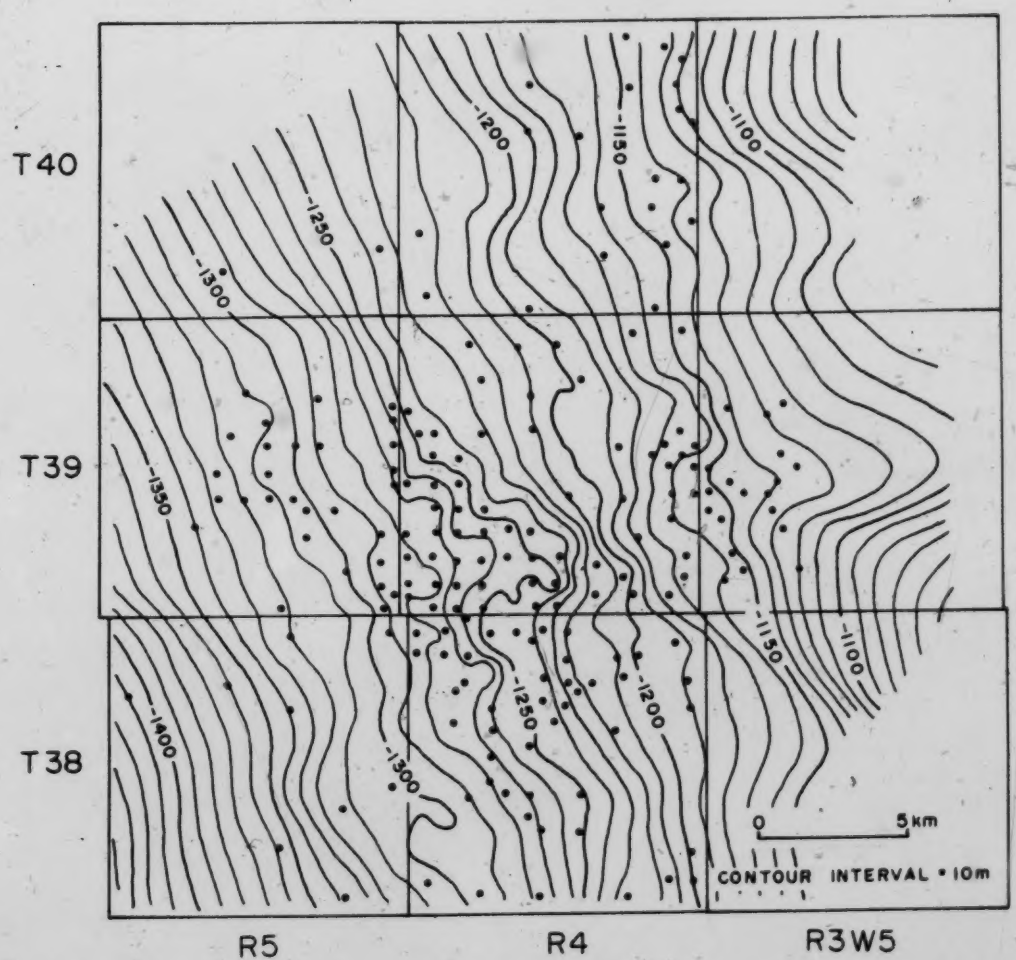


Figure 37. Structure on the top of the Medicine River coal.

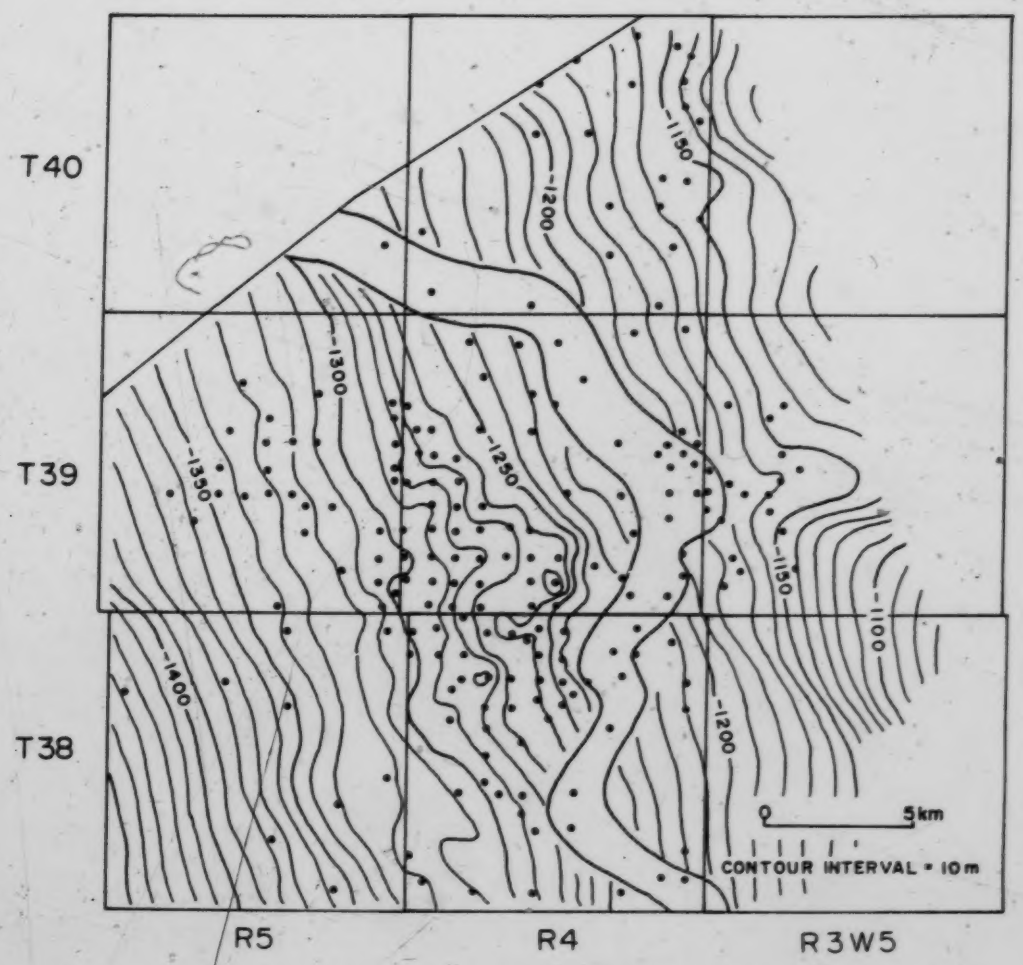


Figure 38. Structure on the top of the Glauconitic coal zone.

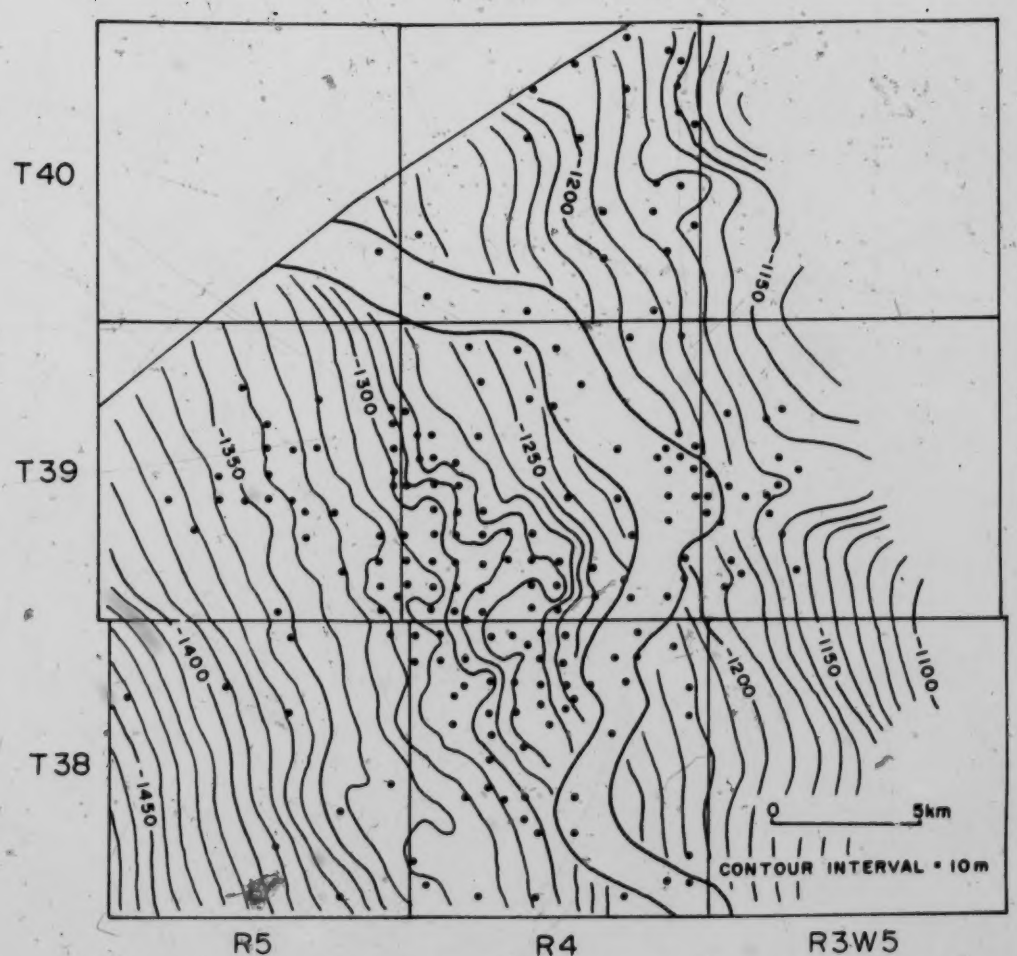


Figure 39. Structure on the top of Marker 1.

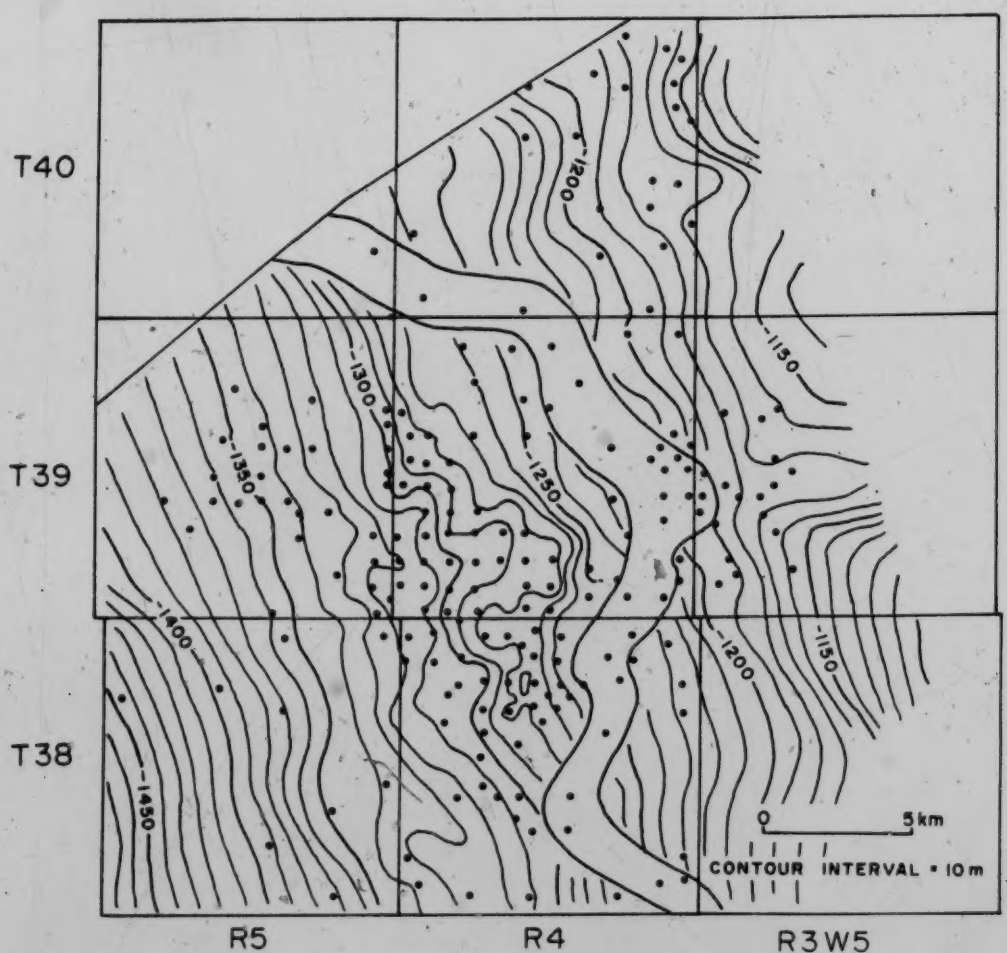


Figure 40. Structure on the top of Marker 2.

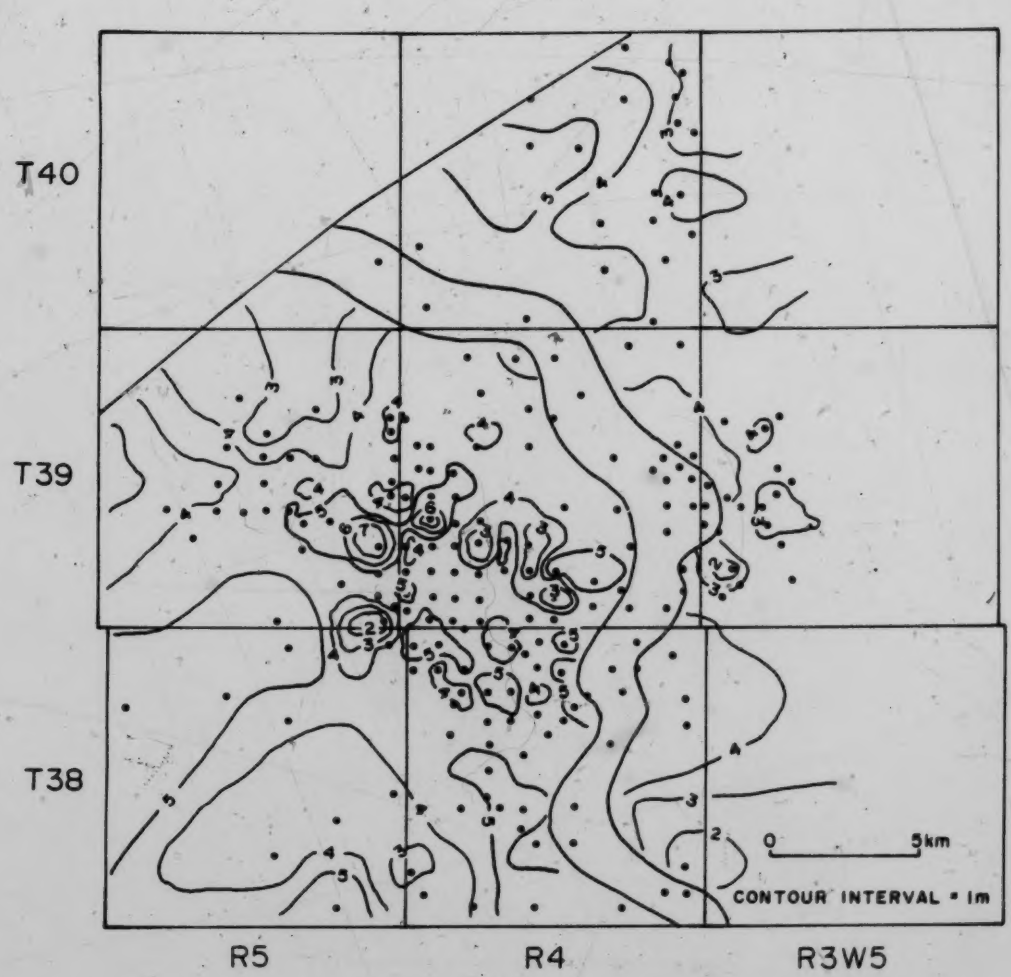


Figure 41. Isopach map of the lower sheet sandstone unit.

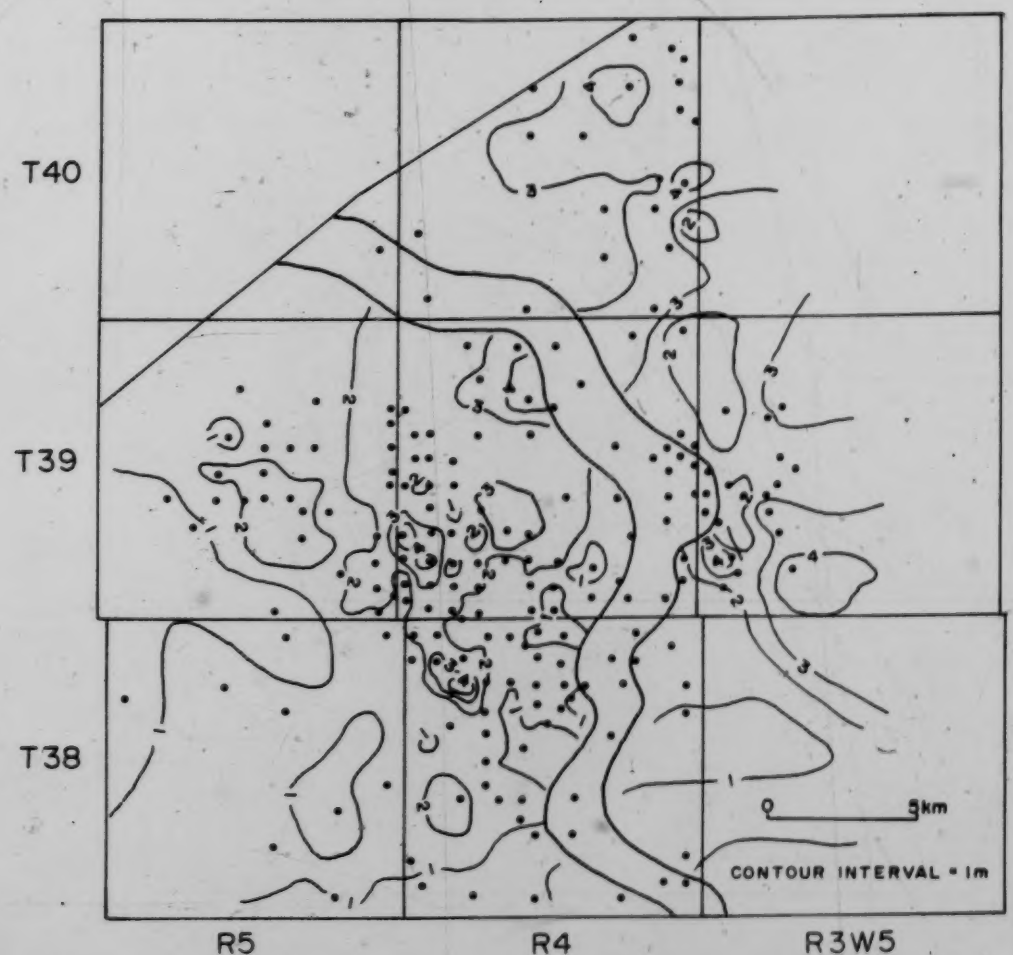


Figure 42. Isopach map of the upper sheet sandstone unit.

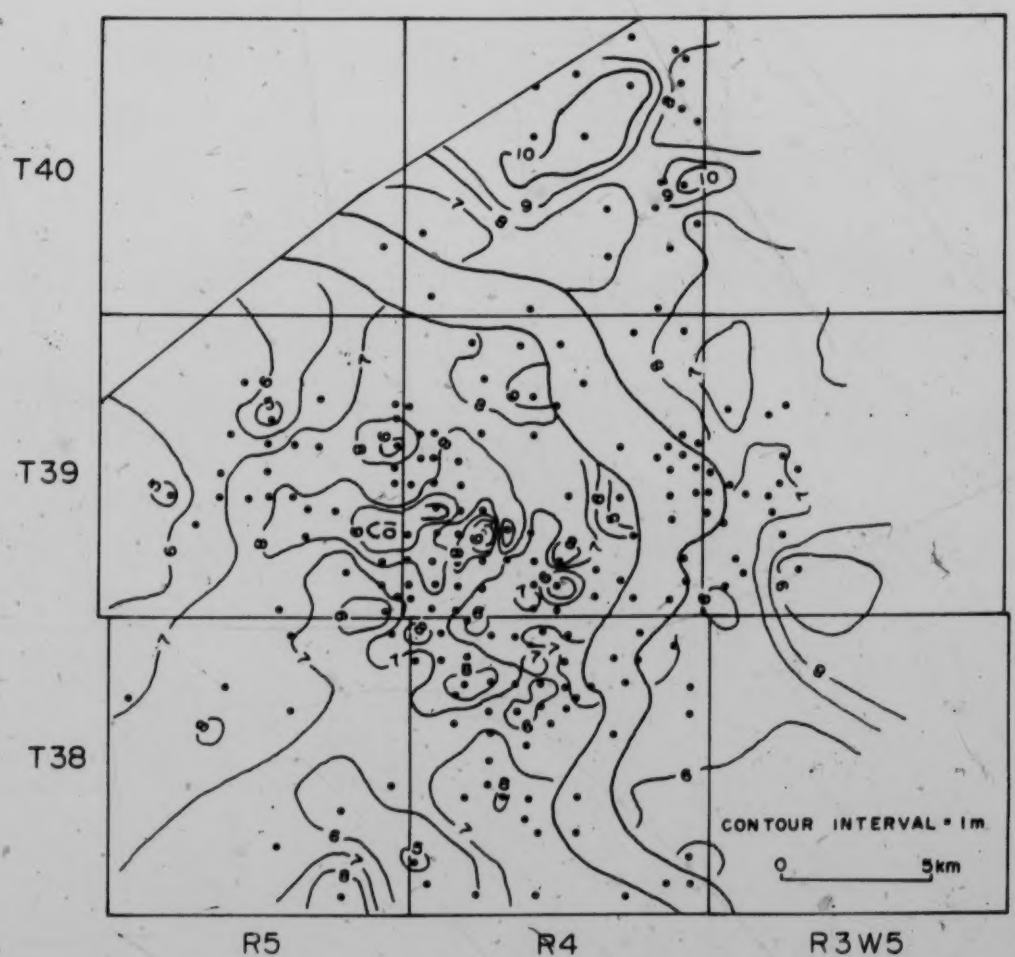


Figure 43. Isopach map of the interval from the top of the upper sandstone unit to the base of the lower sandstone unit.

V. REGIONAL PERSPECTIVE

A. INTRODUCTION

Regional mapping of a study block approximately 200 km by 230 km was done to get a regional perspective of depositional trends of the Glauconitic member in south-central Alberta. It was hoped that by determining major shoreline trends, and by correlating major sandbodies, one could interpret the depositional history of this portion of the basin. The generalized paleogeographic maps (Figures 44 and 45) and cross section L-L' (in pocket) summarize the results of this mapping project. Approximately 1900 wells were examined in total. Regional mapping of the Hoadley Bar lithosome was done by Chiang (1985), but important lithosomes to the north of Hoadley were not included in that study. Correlation of these northern features to the Hoadley Bar lithosome helped to put regional depositional trends into a clearer perspective.

In the Medicine River Field and surrounding areas, every available well was examined. The lithologic sequences recognized were defined with the use of core descriptions and palynology, giving a relatively high degree of confidence in the resulting map (Figure 30). The much larger study block could not be done with the same data control, however, so only generalized lithologic sequences could be mapped. These sequences were identified on the basis of geophysical log character, using the Medicine River coal as an upper datum, and where present, an Ostracode marker (a distinctive sandstone unit) as a lower datum (see cross section L-L', in pocket).

Major sandstones in this study area form a series of coarsening-upward sequences. Each coarsening-upward sequence consists of mudstone at the base to sandstone towards the top. The tops of these sequences appeared to make excellent datums and could be correlated over relatively large distances. The coarsening-upward sequences were identified as the Sheet Sands lithosome, the Hoadley Bar lithosome, the Bigoray Bar lithosome, and the Upper Mannville Bar lithosome. They have a linear geometry, and are believed to represent extensive shoreline trends. These trends have a southwest to northeast orientation, spanning from the western basin margin to the Wainwright Ridge, a distance of over 200 kilometres (See Figure 44). It must be firmly stated, however, that the boundaries shown, particularly of the Bigoray and Upper Mannville Bar lithosomes are generalized and simplified. The main purpose of

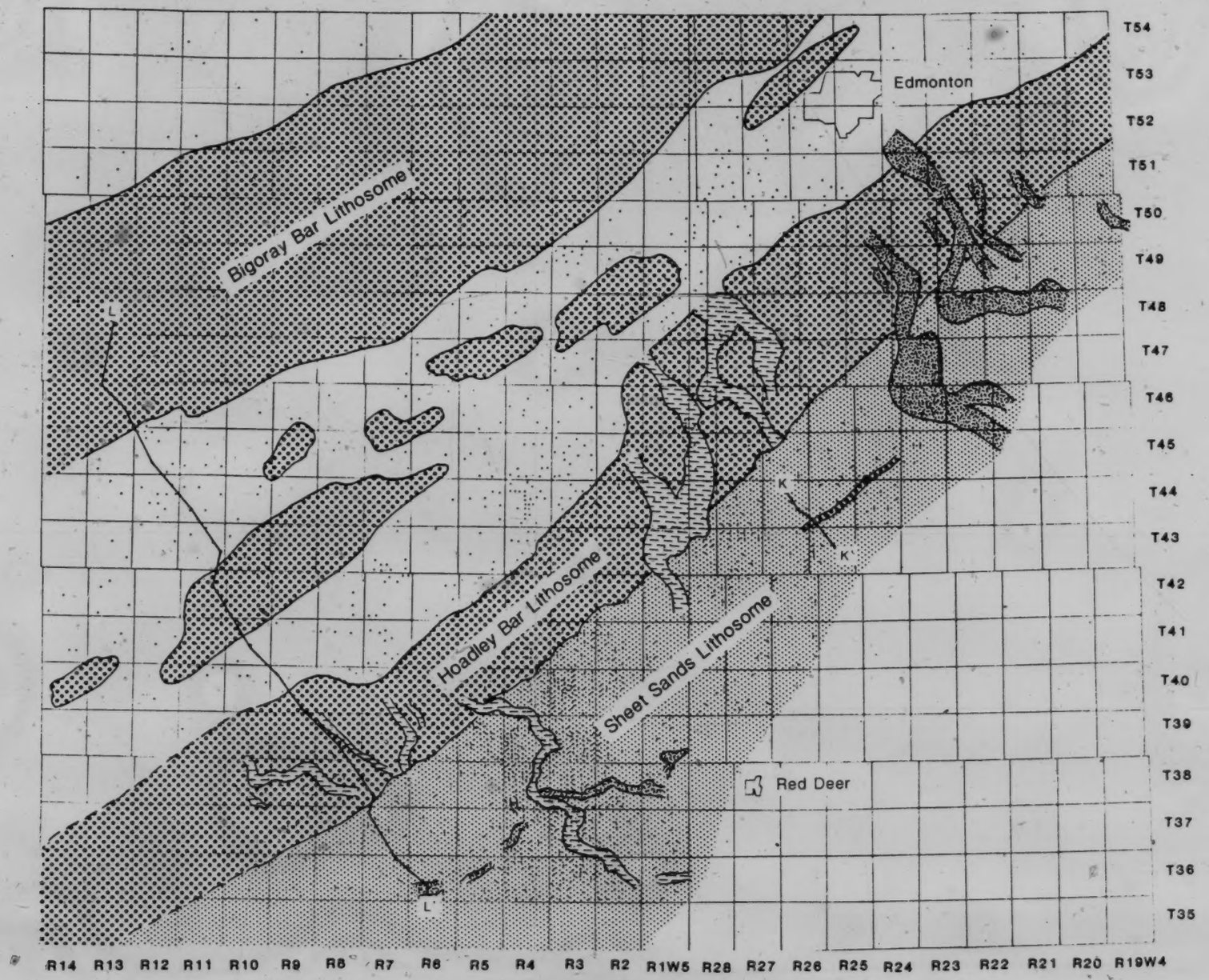


Figure 44. Paleogeographic map showing approximate boundaries of major lithosomes of the Glauconitic member. The locations of cross sections K-K' and L-L' are shown for reference.

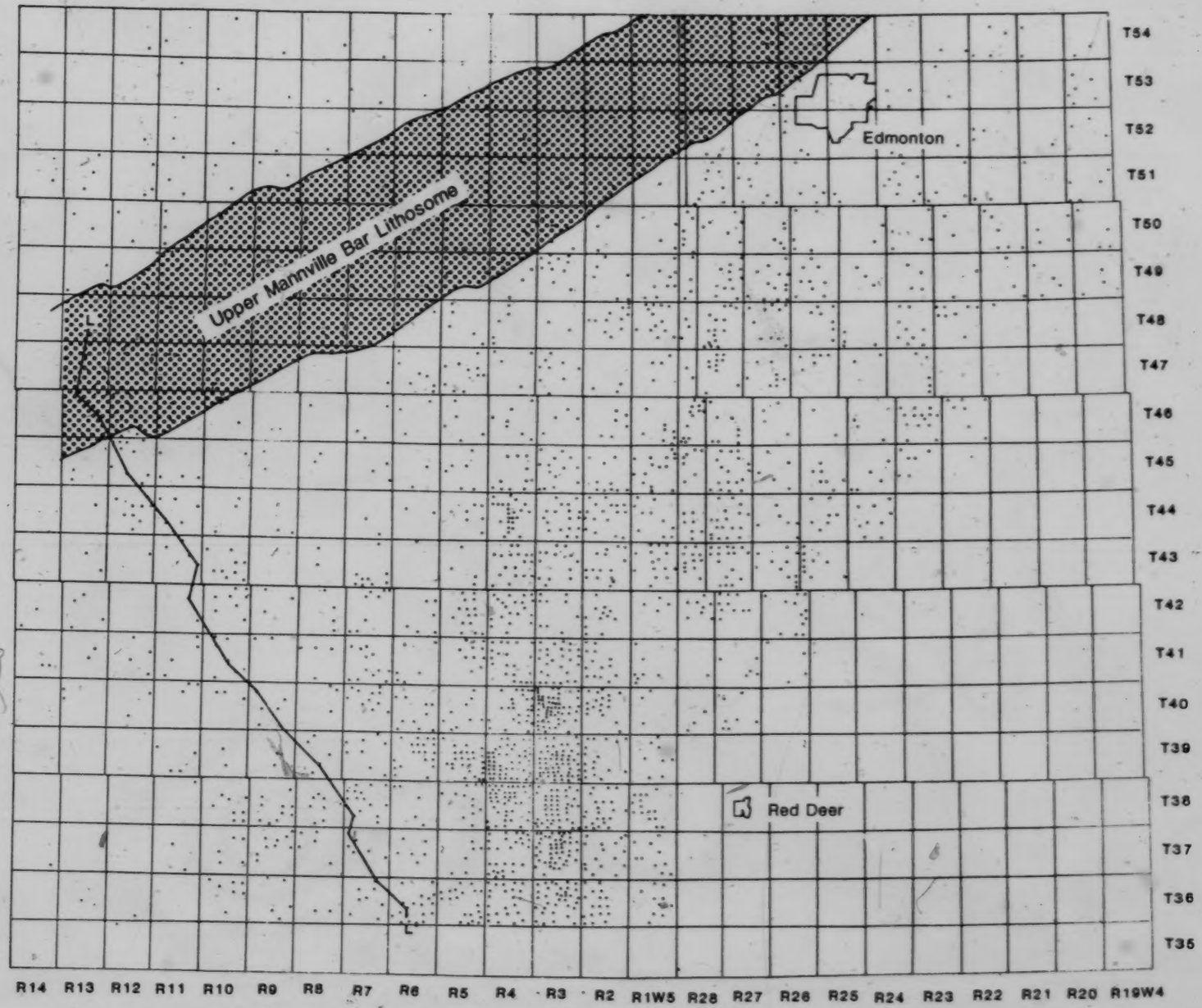


Figure 45. Paleogeographic map showing approximate boundaries of the Upper Mannville Bar lithosome. This lithosome overlies the Glauconitic member and is considered upper Mannville in age.

mapping these lithosomes was to determine shoreline and depositional trends. Well control of only one to three wells per township is not sufficient to give precise boundaries.

Channel sequences identified within the Hoadley Bar lithosome are mapped with relatively good well control but will likely be subject to modification as more data are acquired. Channel sequences are recognized to the north of the Hoadley Bar lithosome and within the Bigoray and Upper Mannville Bar lithosomes, but these were not mapped due to the sparse well control and the complex nature of these channel sequences.

Each lithosome in Figures 44 and 45 represents a different depositional event and will be described individually. Some of these lithosomes were described in detail in the previous chapter, so they are just highlighted here.

B. SHEET SANDS LITHOSOME

The Sheet Sands lithosome was described in detail in the Medicine River Field area. The reader is urged to review this section if more information is desired. Based on the characteristic geophysical log response, and with the use of the Glauconitic and Medicine River coals for correlation, this lithosome was mapped for a much larger area to the northeast and southwest of the Medicine River Field (Figure 44). A sharp boundary between the Hoadley Bar lithosome and the Sheet Sands lithosome suggests that sheet sandstones that may have occupied a more seaward position, were winnowed and reworked to become incorporated into the bar sandstones of the Hoadley Bar lithosome.

As noted for the Medicine River Field area, the Sheet Sands lithosome may have been formed as a series of wave dominated deltas. The effects of marine reworking were observed in several areas. A clean sandy sequence (possibly a bar feature) with a southwest to northeast orientation in Township 44, Range 25 W4M in Figure 44, indicates that some sandstones were locally reworked (See cross section K-K', in pocket). A mudstone interval between the lower sheet sandstones and the upper coal cap (See Figure 13) may be lagoonal, deposited in a backbarrier setting during progradation northwards of the barrier. The Glauconitic coal caps both the Sheet Sands and the Hoadley Bar lithosomes suggesting a progradation of the coastal plain following deposition of the two lithosomes (See cross section L-L', in pocket).

C. HOADLEY BAR LITHOSOME

The Hoadley Bar lithosome was described in detail for the Medicine River Field area, and was mapped by Chiang (1985). Sandstones of this lithosome have a diagnostic geophysical log character and can be mapped as a major coarsening-upward sequence throughout the regional study area. The Glauconitic coal was used to correlate this lithosome to the Sheet Sands lithosome.

A period of stillstand following deposition of the Sheet Sands lithosome resulted in the formation of barrier sandstones of the Hoadley Bar lithosome. The shallowing-upward trend from marine mudstones at the base, passing upwards through 15 to 35m thick shoreface sandstones to a coal cap (the Glauconitic coal) indicates overall regressive conditions and progradation of the barrier toward the north.

D. BIGORAY BAR LITHOSOME

The Bigoray Bar lithosome is recognized as a a major coarsening-upward sequence, with a southwest to northeast orientation, deposited over the Pembina area and immediately north of the Hoadley Bar lithosome (see Figure 44). The presence of marine mudstones immediately overlying the Bigoray Bar lithosome suggest that a transgression occurred soon after deposition. In cross section L-L' (in pocket), the top of this lithosome is correlated to the top of the Hoadley Bar lithosome. It is not known whether the Bigoray Bar lithosome was deposited before or after the Hoadley Bar lithosome, but a slightly younger age for the Bigoray is suggested.

E. UPPER MANNVILLE BAR LITHOSOME

This Upper Mannville Bar lithosome consists of mudstones at the base, passing upwards through argillaceous sandstones to a coal cap (the Medicine River coal). It overlies the Bigoray Bar lithosome and is stratigraphically higher than the Hoadley Bar lithosome, indicating that it is the youngest of the lithosomes identified (See Figure 45 and cross-section L-L').

The presence of a coal cap (the Medicine River coal) indicates a shallowing-upward trend. It likely formed in response to the regression of the sea towards the north. Sandstones of this lithosome may correlate with the Falher H Member sandstones mapped by Jackson (1985).

The term Upper Mannville Bar is used to differentiate this younger lithosome from the older Bigoray and Hoadley Bar lithosomes. The Upper Mannville Bar lithosome is prominent in the Pembina area, but is not present south of the Hoadley area (See cross section L-L', in pocket).

F. CHANNELLING EPISODES

Major channelling episodes of various ages commonly occur within the nearshore marine sequences. In the Lloydminster area, for instance, several channelling episodes are recognized, each associated with transgressive-regressive cycles (Putnam, 1982). In the Medicine River Field substudy, two channelling episodes are recognized: a pre-Glauconitic coal channel sequence in which the Glauconitic coal is preserved and a post-Glauconitic coal sequence in which the Glauconitic coal is eroded. The Medicine River coal, which lies 15 to 30 metres above the Glauconitic member serves as a datum for both channel sequences.

The pre-Glauconitic coal channel sequence dissects large portions of the Sheet Sands and the Hoadley Bar lithosomes south of the Edmonton area (Figure 44). The Glauconitic coal is preserved in most wells where this channel sequence is recognized. The sequence generally consists of 15 to 40 metres of fining-upward sandstones. Chiang (1985) identified this sequence as the "post-Glauconite sand fluvial deposit." The interpretation given by Chiang (1985) indicates almost complete removal of the northeastern portion of the Sheet Sands and the Hoadley Bar lithosomes south of Edmonton. Findings of the present study, however, indicate that although the northeastern portion is highly dissected by this channelling episode, most of the Sheet Sands and the Hoadley Bar lithosomes are preserved.

An older episode, identified as the post-Glauconitic coal channel sequence is described in the previous chapter. Evidence from the Medicine River Field area suggests that this sequence is estuarine and is dominated by muddy-infilling. It is sinuous and has a southeast to northwest orientation.

G. ECONOMIC IMPLICATIONS

The main reservoir unit of the Medicine River Field consists of the more porous and permeable portions of the Sheet Sands lithosome. The sheet sandstones of this lithosome offer a relatively widespread blanketing reservoir throughout the study area. In the main pool, light gravity oils and an associated gas cap are trapped updip by mudstones of a sinuous channel

sequence. The main pool appears to be situated within a large meander of this sequence. An auxiliary pool and associated gas cap are located to the northwest of the main pool and appear to be trapped updip by relatively impermeable sheet sandstones. The extreme variation in porosity and permeability, and the limited lateral persistence of pay zones, are recognized obstacles for explorationists in this area. Dry wells or wells that produce for only short periods are commonly located close to actively producing wells.

The recognition of two channelling episodes will be of considerable importance in the search for new oil and gas fields in the study area. Muddy channel sequences of the post-Glauconitic coal channelling episode, for instance, are known to be the main trapping agent in the Hoadley, Ferrier, and Medicine River Fields. Similar muddy channel sequences present in other portions of the study area may prove to have equal importance. Sandy channel sequences of the pre-Glauconitic coal channelling episode have good potential as reservoirs. One example is the Sylvan Lake gas field.

Evidence given in this study suggests that many muddy channel sequences may have been deposited in estuaries, as opposed to abandoned fluvial channels, proposed by some previous researchers. The estuarine interpretation supports the presence of tidally-influenced river stretches which may be 60 km or more in length. The abandoned fluvial channel interpretation favours depositional features such as oxbow lakes or delta distributaries. In the latter interpretation, sequences need not be laterally continuous over long distances. The interpretation chosen may, therefore, influence mapping of these sequences.

Major sub-basins may have had considerable effect on sedimentation of the Glauconitic member. A northern sub-basin, resulting from subsidence over the Peace River Arch, appears to have been a major depocentre. A hingeline between shallow marine depositional conditions, represented by barrier sandstones of the Glauconitic member, and the relatively deep marine conditions represented by the thick shales of the Clearwater Formation, was drawn by Jackson (1985) and is supported in this study. The best reservoir potential for the Glauconitic member should be south of this hingeline. Slightly elevated areas of the Paleozoic surface, such as the Pembina High, may have influenced the distribution of bar sandstones. The Bigoray and Upper Mannville Bar lithosomes appear to be particularly well developed over the Pembina High.

VI. SUMMARY AND CONCLUSIONS

The Sheet Sands lithosome in the Medicine River Field exhibits both coarsening-upward and shallowing-upward trends. Regression of the sea and northward progradation of the shoreline, led to the development of the sheet sandstones in this lithosome. Sediments are believed to have accumulated in a series of wave-dominated deltas. Isopach maps of the sheet sandstones indicate considerable variation in thickness over relatively short distances, suggesting localized depositional conditions. Results of the core study indicate that beds vary in thickness from less than 1 cm to more than 40 cm, and have very limited lateral extent. Attempts to correlate beds from one cored interval to the next were not successful, even between wells that were 600 to 800m apart. Synaeresis cracks, spiral-shaped trace fossils (identified as *Gyrolithes* sp.) and pyritic and sideritic concretions are brackish-water indicators commonly observed in the sheet sandstones. The grain size and sedimentary and biogenic structures were observed to vary considerably between beds. In addition, truncated bioturbated tops of beds are common. This latter feature may be indicative of alternating rapid and slow depositional rates. Many intervals appear similar to shoreline-associated amalgamated sandstones described in ancient analogues. A low diversity of dinoflagellates, consisting predominantly of *Muderongia* sp., was recovered from many sampling intervals. The low diversity may be indicative of a restricted marine to brackish depositional environment. The combined evidence supports a deltaic interpretation.

Following deposition of the Sheet Sands lithosome, a period of equilibrium between deposition and subsidence may have occurred, resulting in stillstand conditions and the formation of the Hoadley Bar lithosome to the north. The Hoadley Bar lithosome consists of thick and relatively continuous shoreface sandstones as opposed to the much thinner, amalgamated sandstones in the Sheet Sands lithosome. A sharp boundary between the Sheet Sands lithosome and the Hoadley Bar lithosome indicates that some sheet sandstones that may have been present prior to stillstand conditions were reworked and winnowed. Mapping of the Hoadley Bar lithosome confirms the existence of a shoreline trend extending from the Foothills in the southwest to the city of Edmonton in the northeast, a distance of over 200 km. A coal cap (Glauconitic coal) overlies both the Sheet Sands lithosome and the Hoadley Bar lithosome,

indicating the progradation of a coastal plain and associated peat swamps after deposition of the two lithosomes.

Mapping of the numerous channel sequences was simplified considerably by classifying them as channelling episodes. Two episodes of channelling are recognized in the study area. The older episode is one of predominantly sand-infilling with a variable orientation of channels, and is only partially preserved in many localities. This sequence may represent delta distributaries supplying sediments to the sheet sandstones of the Medicine River Field, or may be estuarine. Based on evidence such as mud couplets, tidal bundles and bioturbation structures, an estuarine interpretation is favoured. This sequence is commonly capped by the Glauconitic coal zone, which distinguishes it from a younger channelling episode in which the Glauconitic coal zone was eroded. The younger episode produced muddy, and lesser amounts of sandy channel sequences. Because of exceptional well control, channelling of this episode could be mapped in great detail, showing the maximum widths and depths of channelling, and the positions of meander belts. The presence of *Muderongia* sp. indicates a marine influence during deposition, suggesting that this channelling episode is also estuarine in nature.

Downcutting of 30 to 40 metres in many of the channel sequences of both episodes, may have been the result of incisement due to a drop in base level during regressions. With the rise of base level during a following transgression, the incised channels began infilling. For the Hoadley Bar lithosome, this interpretation offers an alternative to the tidal channel interpretation given by several previous researchers. For the Sheet Sands lithosome, this interpretation offers an alternative to the oxbow lake and abandoned distributary channel interpretations.

A series of younger barrier trends, identified as the Bigoray and Upper Mannville Bar lithosomes, indicates the general progradation of shorelines to the north. The Bigoray Bar lithosome was deposited immediately north of the Hoadley area and throughout the Pembina area. Correlation of the tops of coarsening-upward sequences in this study indicated that sandstones in the Bigoray Bar lithosome are stratigraphically equivalent to those of the Hoadley Bar lithosome. The Upper Mannville Bar lithosome overlies the Bigoray Bar lithosome. It displays a shallowing-upward trend, with mudstones at the base passing upwards through shoreface sandstones to a coal cap (the Medicine River coal). The Upper Mannville Bar lithosome and the Medicine River coal are believed to have been deposited during a final

northward retreat of the boreal sea from the study area.

A major sub-basin in the Peace River area had a considerable effect on sedimentation of the Glauconitic member. A distinct hingeline between shallow marine depositional conditions, represented by the barrier sequences of the Glauconitic member, and relatively deep marine depositional conditions, represented by thick mudstone sequences of the Clearwater Formation, is supported by data in this study. A series of thick fluvial sandstones and laterally continuous coals (including the Medicine River coal) confirm the existence of a widespread coastal plain environment following deposition of the Glauconitic member. The thinning and splitting of many of these coal seams towards the north, however, indicate that a marine influence persisted in that direction, probably due to the effects of the sub-basin.

A rising mountain belt along the western basin margin appears to have been a major source of clastics for the Glauconitic member. The thick chert and quartzite pebble conglomerates located in the Hoadley Bar lithosome were likely derived from a fluvial source to the southwest of the study area, rather than from a direct southerly source. The sandstones of the Hoadley, Bigoray and Upper Mannville Bar lithosomes may also have been derived largely from this southwesterly source, reflecting a strong tectonic influence on sedimentation throughout the study area.

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Appendix A

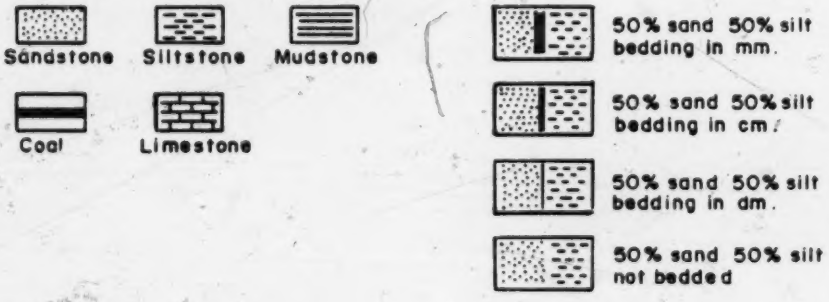
Core logs

LEGEND - GRAPHIC LOGGING FORM

Sedimentary Structures

- H Homogeneous (massive appearance)
- Climbing ripples
- Planar cross beds
- Trough cross beds
- Low angle to horizontal laminations
- Vague - faintly laminated
- Wavy laminations – wavy bedding
- Load cast
- Flame structure
- Rip up clasts
- Convolute laminae or bedding
- Slump structure or flowage
- Rooting structure
- Burrow, vertical, horizontal
- Weakly bioturbated
- Moderately bioturbated
- Strongly bioturbated
- Shells (undifferentiated)

Gross Lithology (And Bedding Scale)



Constituents And Accessories

G Glauconite
P Pyrite
B Bentonite
S Siderite
Y Sulphur
M Micaceous
* Bitumen
Carbonaceous debris (plant remains)
Carbonaceous laminae
Oz Concretion, z = mineralogy

0 - 5% — one symbol
6 - 25% — two symbols

Sorting

5 Very well sorted
4 Well sorted
3 Moderately sorted
2 Poorly sorted
1 Very poorly sorted

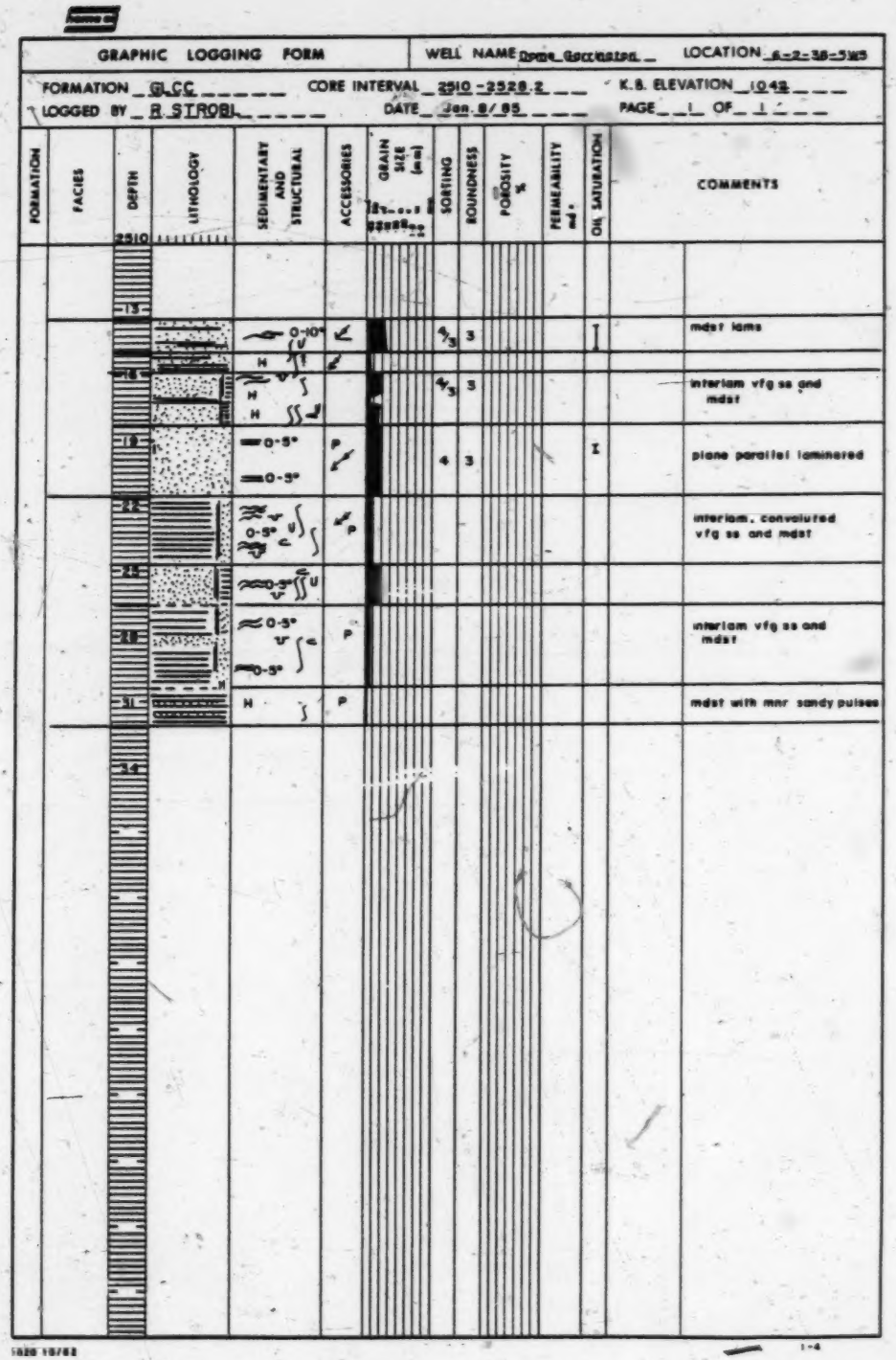
Roundness

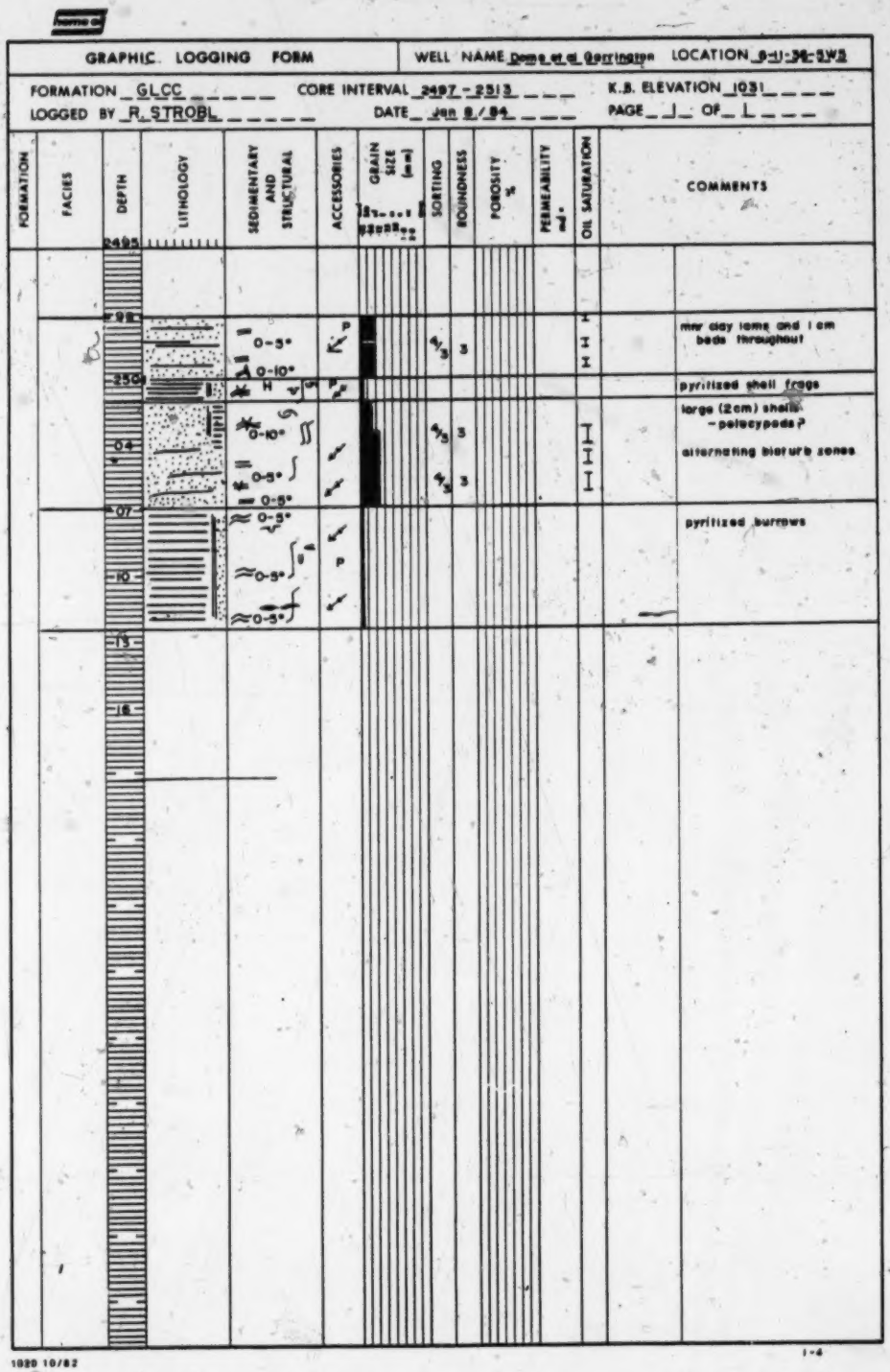
1 Very angular
2 Angular
3 Sub-angular
4 Sub-rounded
5 Rounded
6 Well-rounded

Abbreviations Used

GLCC = Glauconitic
Ss = sandstone
Slst = siltstone
Mdst = mudstone
F.U.S. = fining upward sequence
ΔT = sonic
γ = gamma
calc = calcareous
carb = carbonaceous

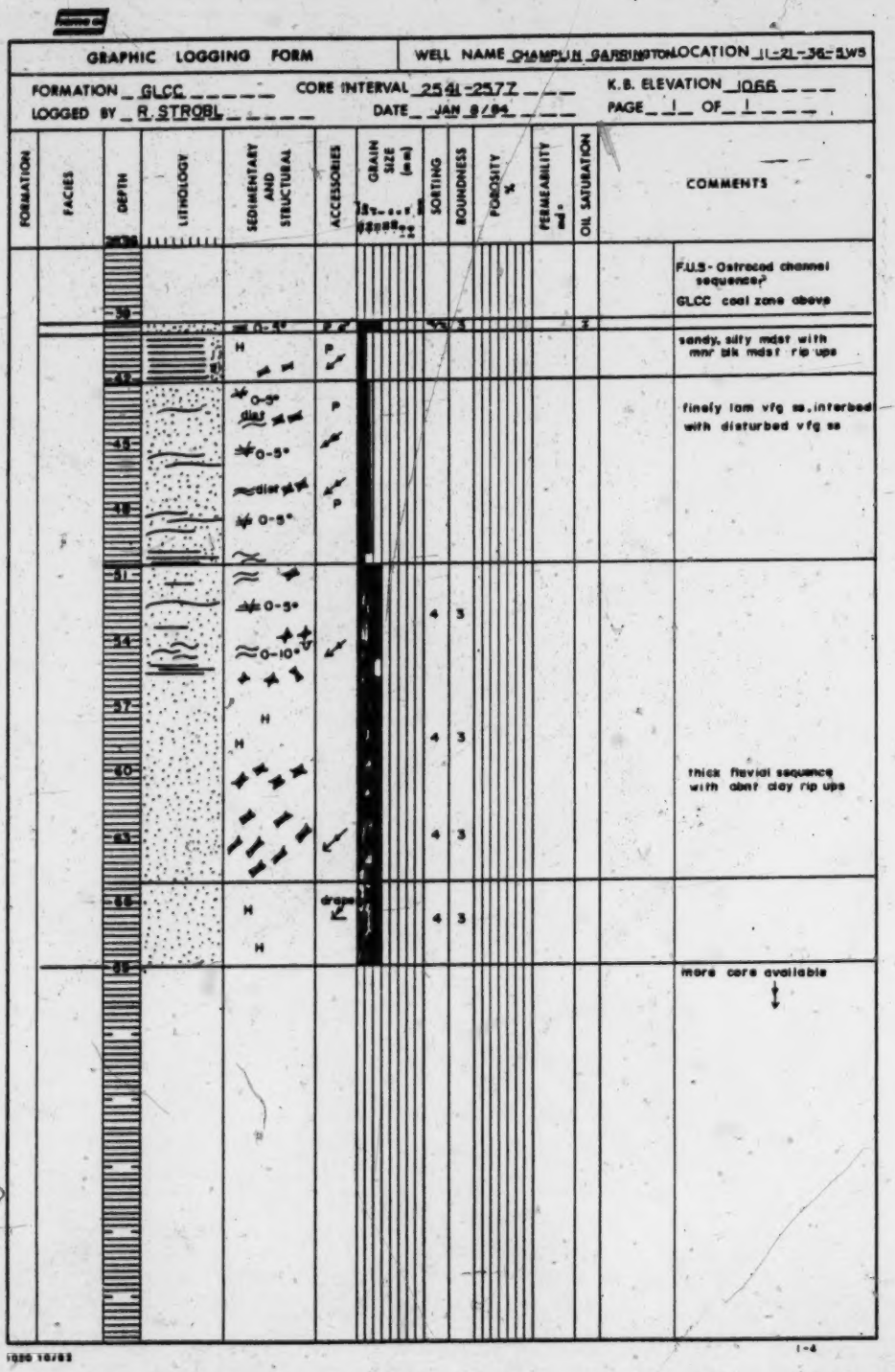
v = very
vfg = very fine grained
fg = fine grained
mnr = minor
abnt = abundant
conc = concretion
biot = bioturbated
alt = alternating


GRAPHIC LOGGING FORM
WELL NAME Dome Gochnauer
LOCATION 6-2-38-5W5
FORMATION GLCC
CORE INTERVAL 2910 - 3528.2
K.B. ELEVATION 1042
LOGGED BY R. STROBL
DATE Jan. 8/85
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md
OIL SATURATION
COMMENTS
2910
mdst lams
interlam vfg ss and mdst
plane parallel laminated
interlam. convoluted vfg ss and mdst
interlam vfg ss and mdst
mdst with mnr sandy pulses


GRAPHIC LOGGING FORM
WELL NAME Dome et al Gerrington LOCATION 9-1-36-9W2
FORMATION GLCC
CORE INTERVAL 2497 - 2513
K.B. ELEVATION 1031
LOGGED BY R. STROBL
DATE Jan 8/84
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md.
OIL SATURATION
COMMENTS
2495
2498
2500
04
07
10
13
16
0-5°
0-10°
0-5°
0-10°
0-5°
0-5°
0-5°
0-5°
P
P
P
P
H
3/3
3/3
3
3
3
thin clay lams and 1 cm beds throughout
pyritized shell frags
large (2cm) shells - pelecypods?
alternating bioturb zones
pyritized burrows

1920 10/82

1-4



GRAPHIC LOGGING FORM

WELL NAME CHAMPLIN GARRINGTON LOCATION 11-21-36-5W5

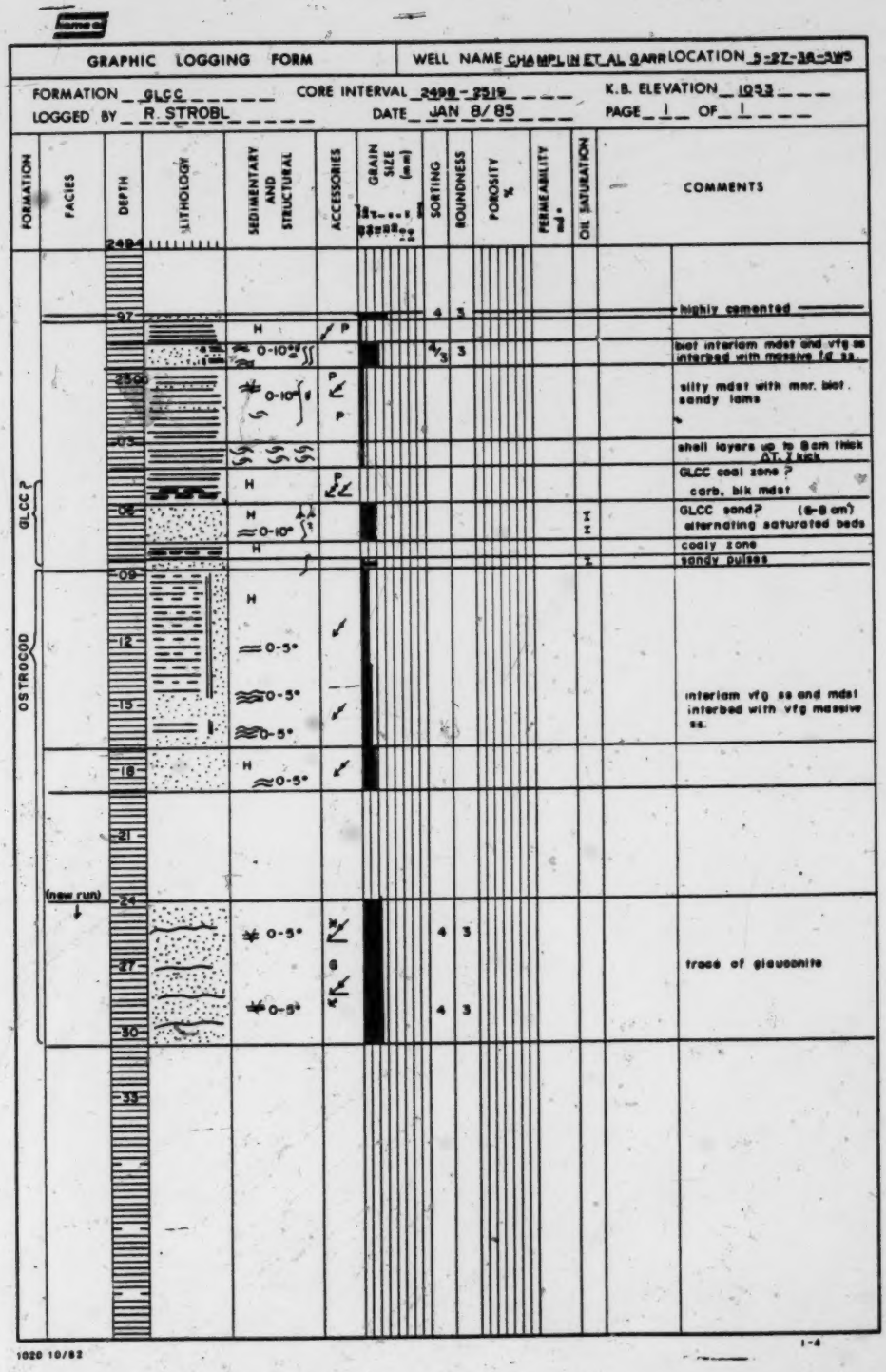
FORMATION GLCC CORE INTERVAL 2541-2577 K.B. ELEVATION 1066

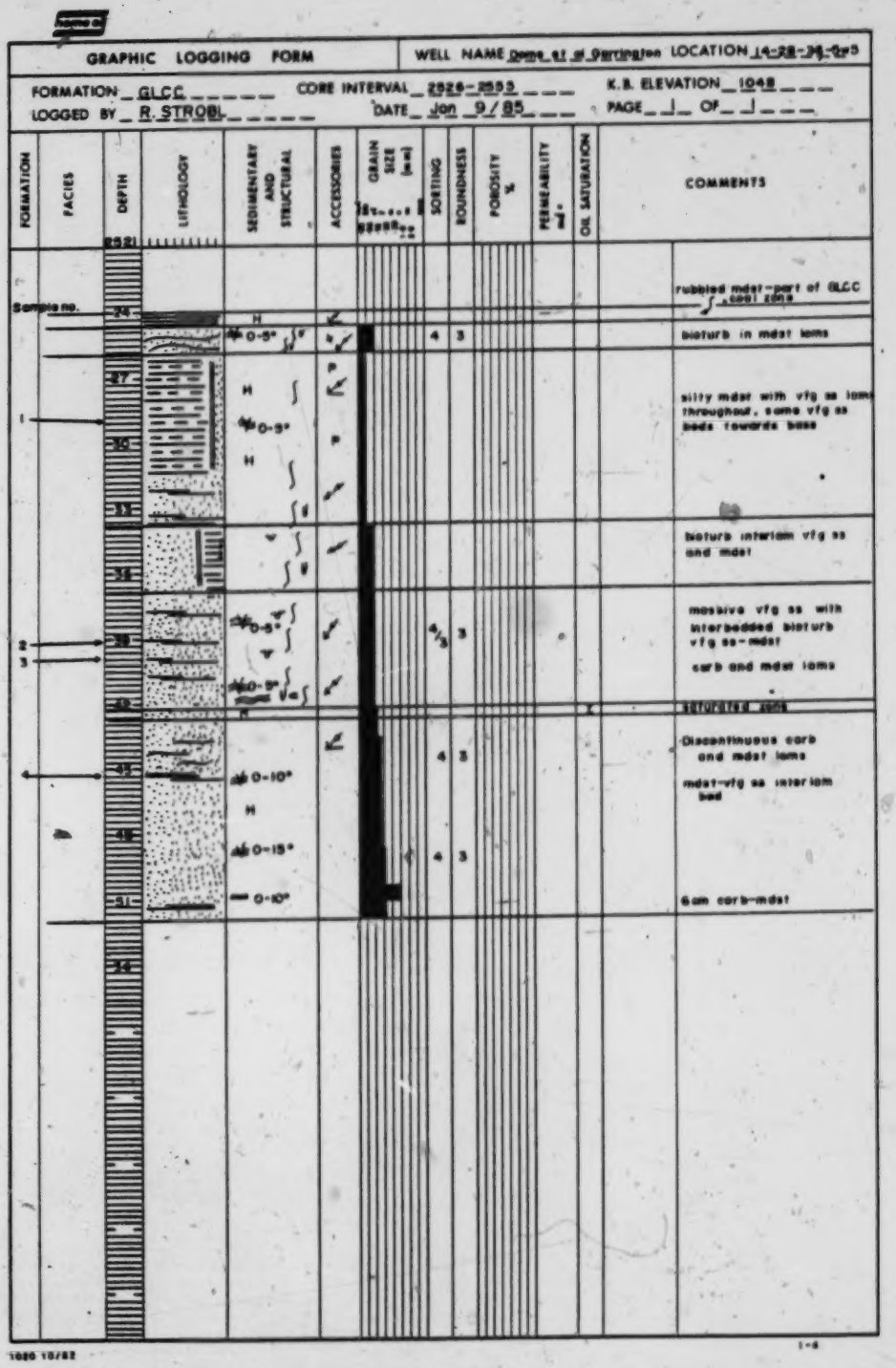
LOGGED BY R. STROBL DATE JAN 8/84 PAGE 1 OF 1

DEPTH	COMMENTS
2536	F.U.S - Ostracod channel sequence? GLCC coal zone above
2542	sandy, silty mdst with mnr blk mdst rip ups
2545	finely lam vfg ss, interbed with disturbed vfg ss
2551	
2554	
2557	
2560	thick fluvial sequence with abnt clay rip ups
2563	
2565	
2568	more core available

1080 10/83

1-4

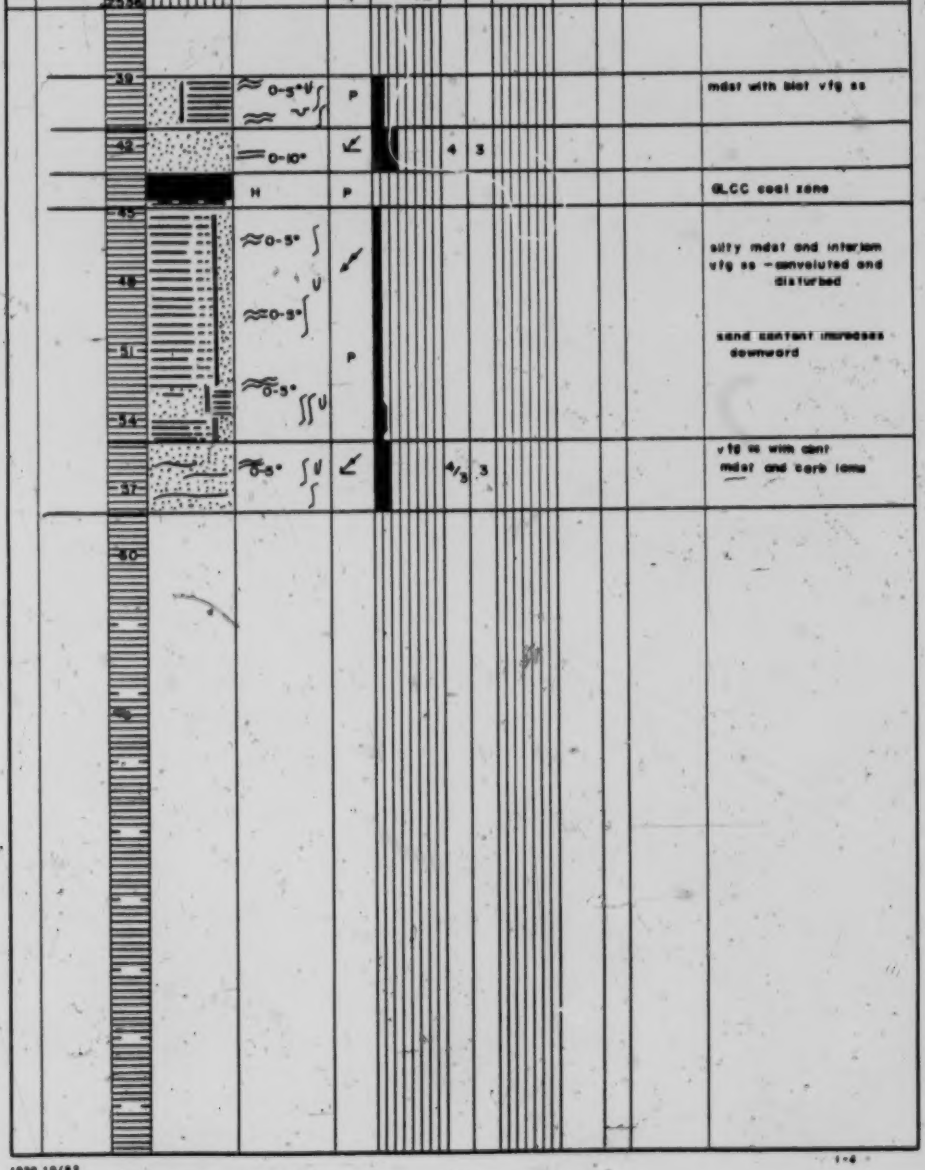

GRAPHIC LOGGING FORM
WELL NAME CHAMPLIN ET AL GARR LOCATION 5-27-38-3W5
FORMATION GLCC
CORE INTERVAL 2498 - 2519
K.B. ELEVATION 1953
LOGGED BY R. STROBL
DATE JAN 8/85
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md
OIL SATURATION
COMMENTS
GLCC ?
OSTRACOD
2494
97
2500
03
06
09
12
15
18
21
(new run)
24
27
30
33
highly cemented
biot interlam mdst and vfg ss interbed with massive fg ss
silty mdst with mnr. biot. sandy lams
shell layers up to 8cm thick
GLCC coal zone ?
carb. blk mdst
GLCC sand? (6-8 cm)
alternating saturated beds
coaly zone
sandy pulses
interlam vfg ss and mdst interbed with vfg massive ss.
trace of glauconite
1020 10/82
1-4


GRAPHIC LOGGING FORM
WELL NAME Dome et al Partington LOCATION 14-28-24-6W5
FORMATION GLCC
CORE INTERVAL 2526-2553
K.B. ELEVATION 1048
LOGGED BY R. STROBL
DATE Jan 9/85
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md
OIL SATURATION
COMMENTS
2521
Sample no.
24
H
0-5°
4
3
rubbled mdst-part of GLCC coal zone
bioturb in mdst loms
27
30
33
H
0-5°
H
P
P
silty mdst with vfg ss lams throughout, some vfg ss beds towards base
bioturb interlam vfg ss and mdst
36
39
42
0-5°
0-5°
4/3
3
massive vfg ss with interbedded bioturb vfg ss-mdst
carb and mdst loms
BIOTURBATED ZONE
45
48
51
0-10°
H
0-15°
0-10°
4
3
4
3
Discontinuous carb and mdst loms
mdst-vfg ss interlam bed
6cm carb-mdst
54
1020 10/82
1-6

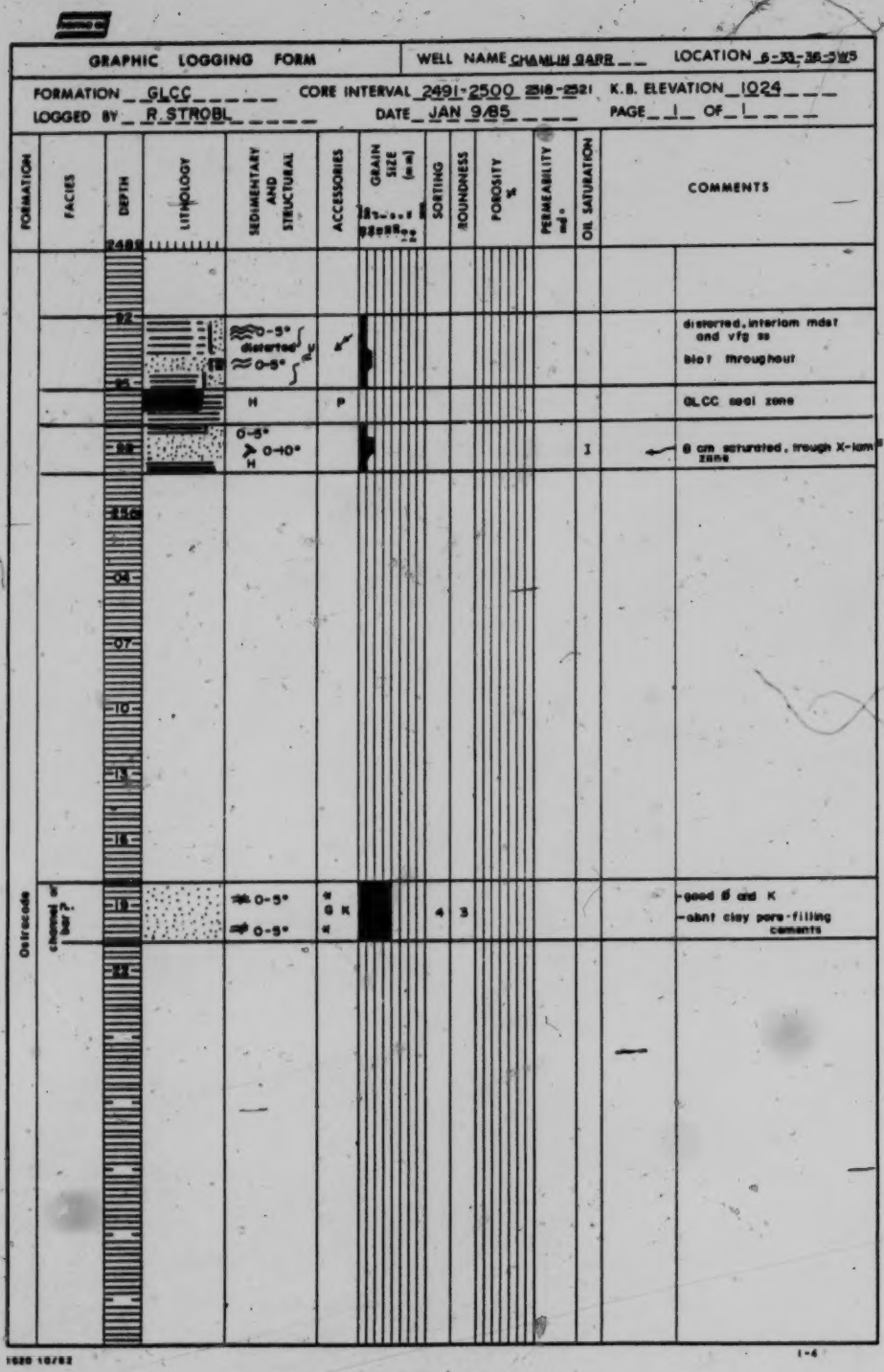
GRAPHIC LOGGING FORM — WELL NAME Dome et al Barrington — LOCATION B-30-34-31W5

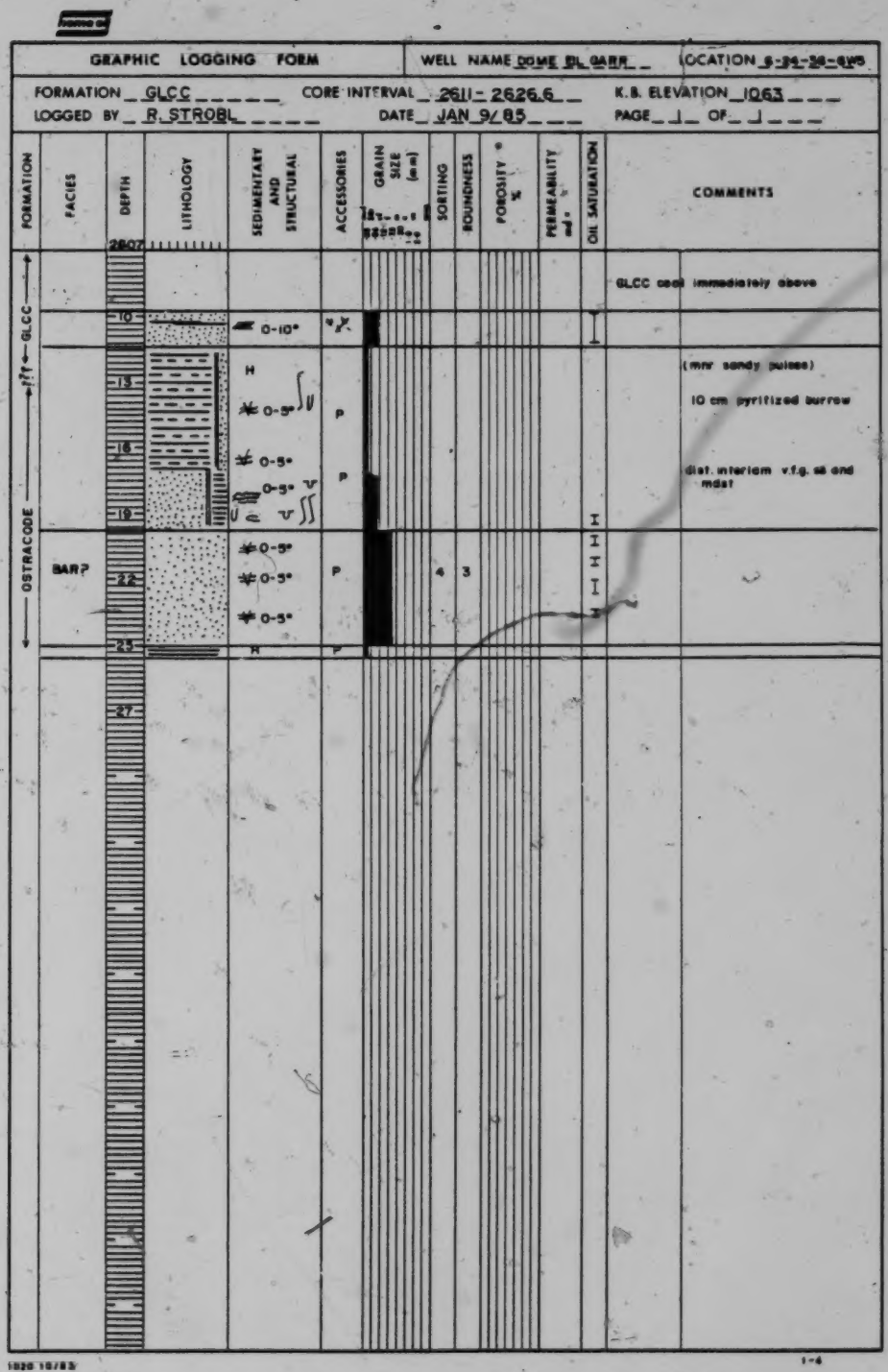
FORMATION GLCC — CORE INTERVAL 2538-2552 — K.B. ELEVATION 1039

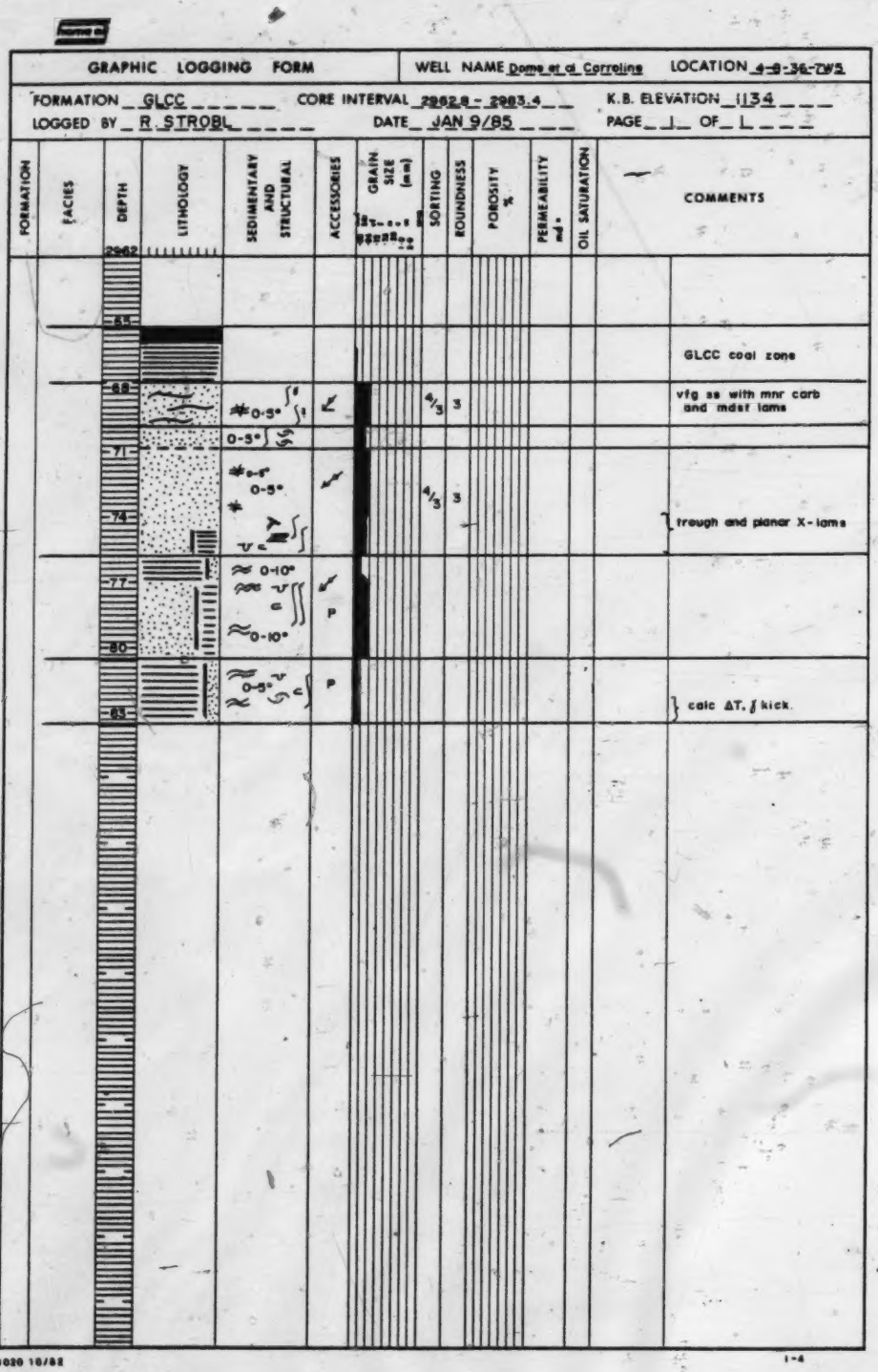
LOGGED BY R. STROBL — DATE JAN 9/85 — PAGE 1 OF 1



1020 10/82


GRAPHIC LOGGING FORM
WELL NAME CHAMLIN GAPR
LOCATION 6-33-36-5W5
FORMATION GLCC
CORE INTERVAL 2491-2500 2518-2521
K.B. ELEVATION 1024
LOGGED BY R. STROBL
DATE JAN 9/85
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md
OIL SATURATION
COMMENTS
2489
92
95
98
01
04
07
10
13
16
19
22
0-5° distorted
0-5°
H
P
0-5°
0-10°
H
I
distorted, interlam mdst and vfg ss
bio? throughout
GLCC coal zone
8 cm saturated, trough X-lam zone
Ostracode
channel or bar?
0-5°
0-5°
G
K
4
3
good Ø and K
-abnt clay pore-filling cements
1020 10/82
1-4


GRAPHIC LOGGING FORM
WELL NAME DOME PL BARR
LOCATION S-34-38-6W5
FORMATION GLCC
CORE INTERVAL 2611 - 2626.6
K.B. ELEVATION 1063
LOGGED BY R. STROBL
DATE JAN 9/85
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md
OIL SATURATION
COMMENTS
2607
GLCC
OSTRACODE
BARR
10
13
16
19
22
25
27
0-10°
0-5°
H
P
4
3
GLCC coal immediately above
(mm sandy pulses)
10 cm pyritized burrow
dist. interlam v.f.g. ss and mdst
1826 10/83
1-4


GRAPHIC LOGGING FORM
WELL NAME Dome et al Correlins
LOCATION 4-8-36-2W2
FORMATION GLCC
CORE INTERVAL 2962.8 - 2983.4
K.B. ELEVATION 1134
LOGGED BY R. STROBL
DATE JAN 9/85
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md
OIL SATURATION
COMMENTS
2962
65
68
71
74
77
80
83
0-5°
0-10°
4/3
3
GLCC coal zone
vfg ss with mnr carb and mdst lams
trough and planar X-lams
calc ΔT, ∫ kick.
1020 10/82
1-4

GRAPHIC LOGGING FORM

WELL NAME DEKALB ET AL RIGNUS LOCATION 11-22-38-7W5

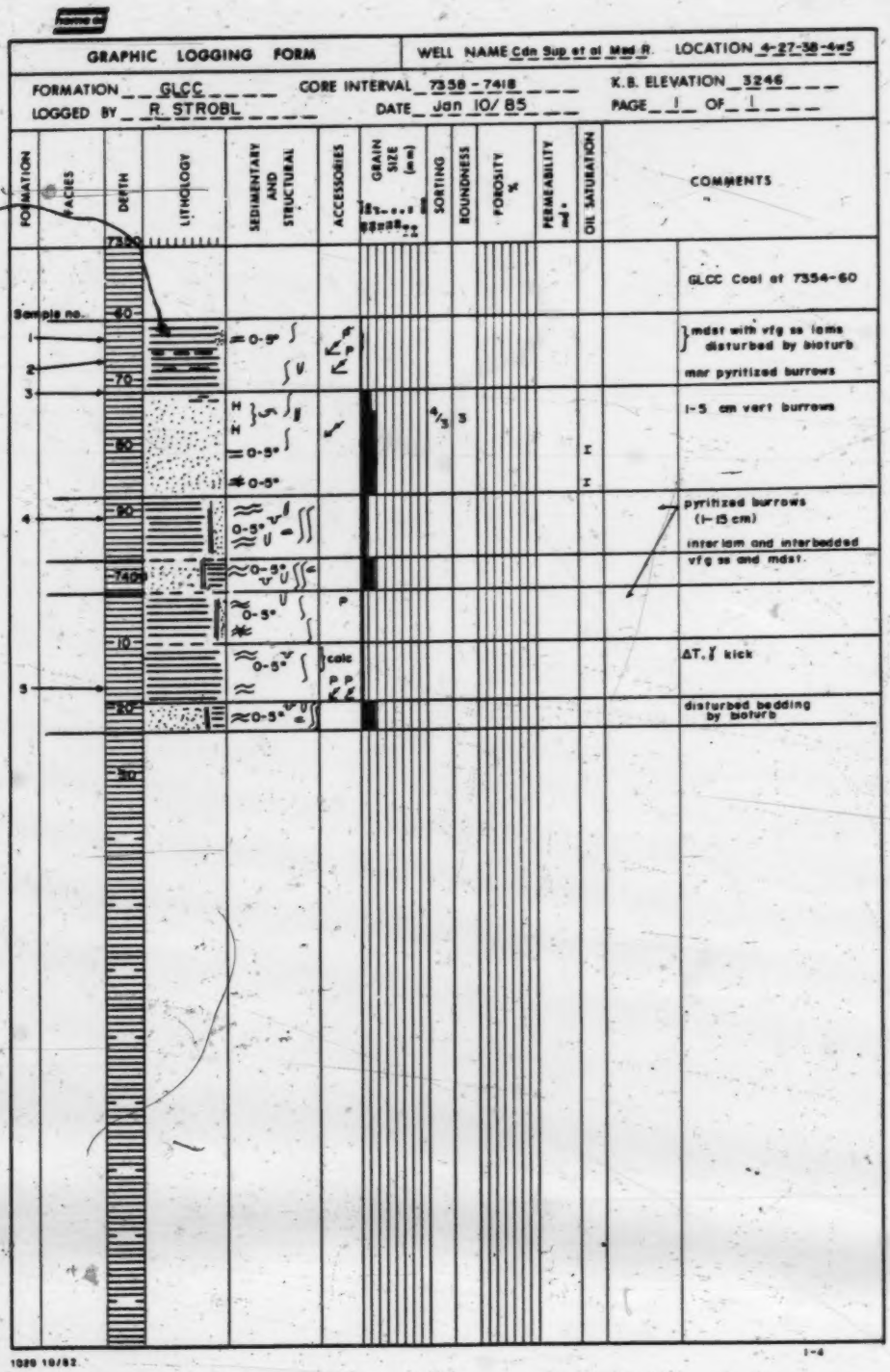
FORMATION GLCC CORE INTERVAL 2862 - 2873 K.B. ELEVATION 1136

LOGGED BY R STROBL DATE JAN 9/85 PAGE 1 OF 1

FORMATION	FACIES	DEPTH	LITHOLOGY	SEDIMENTARY AND STRUCTURAL	ACCESSORIES	GRAIN SIZE (mm)	SORTING	ROUNDNESS	POROSITY %	PERMEABILITY md.	OIL SATURATION	COMMENTS
		2860										
		63										
				H								GLCC coal zone
		66		carb								rubbled
				0-5°								churned sandy-muddy mix
		69		0-5°			4/3	3				coally lams and carby beds
		72		5-15°								as becomes less argillaceous
		75										

1020 10/82

1-4


GRAPHIC LOGGING FORM
WELL NAME Cdn Sup et al Med R. LOCATION 4-27-38-4w5
FORMATION GLCC
CORE INTERVAL 7358 - 7418
K.B. ELEVATION 3246
LOGGED BY R. STROBL
DATE Jan 10/ 85
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md
OIL SATURATION
COMMENTS
7350
GLCC Coal at 7354-60
Sample no.
40
1
2
70
3
80
90
4
740
10
5
20
30
0-5°
mdst with vfg ss lams disturbed by bioturb
mor pyritized burrows
1-5 cm vert burrows
pyritized burrows (1-15 cm)
interlam and interbedded vfg ss and mdst
ΔT. ↑ kick
disturbed bedding by bioturb
1-4

Form 4

GRAPHIC LOGGING FORM — WELL NAME CON-SUP-MED B — LOCATION 12-27-38-4W5

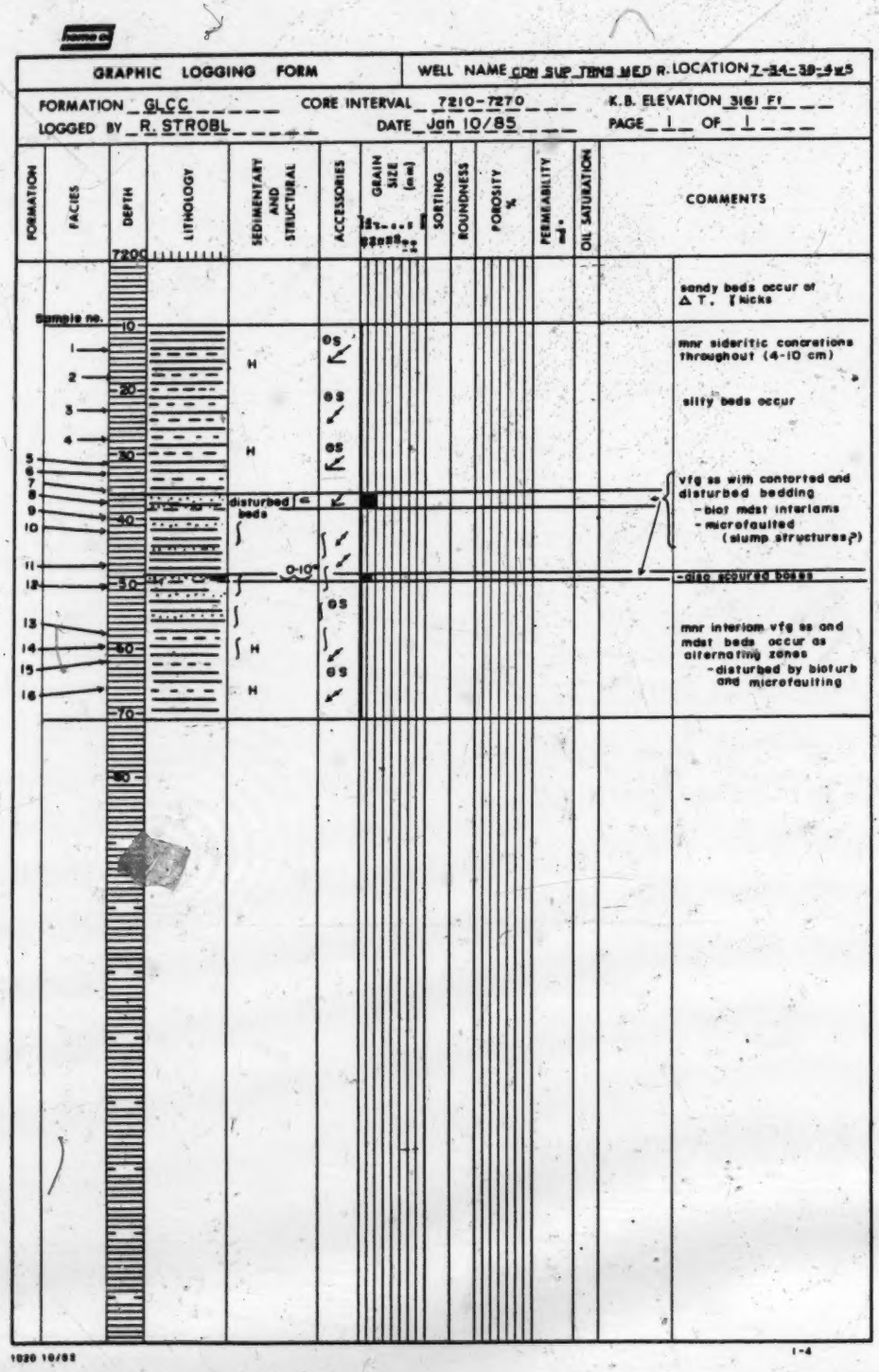
FORMATION GLCC — CORE INTERVAL 7310 - 7370 — K.B. ELEVATION 3217

LOGGED BY R STROBL — DATE JAN 10/85 — PAGE 1 OF 1

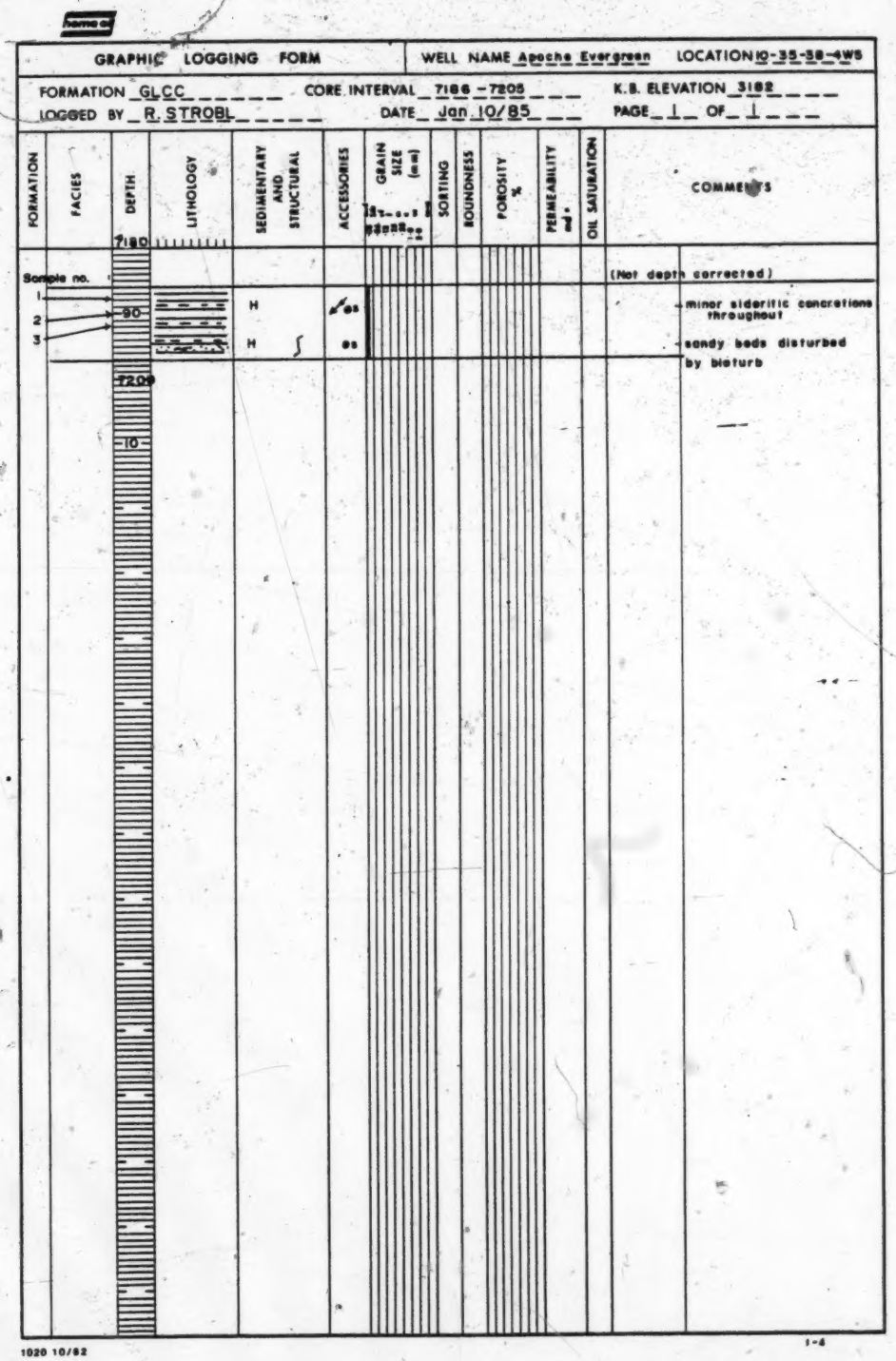
FORMATION	FACIES	DEPTH	LITHOLOGY	SEDIMENTARY AND STRUCTURAL	ACCESSORIES	GRAIN SIZE (mm)	SORTING	ROUNDNESS	POROSITY %	PERMEABILITY md.	OIL SATURATION	COMMENTS
		7300										GLCC coal overlies shale
		10		H ≈0-3°								
		20		H			4	3			I	silt blst and saturated 15 - 25 cm thick zones
		30		H 0-5° 5-10°			4	3			I I I	mnr mdst lams and drapes
		40		≈ V ≈0-5°	P							convoluted, interlam mdst and vfg ss
		50		≈0-5° V								
				≈0-5°								sandy pulses in mdst
		60										sl. calc at base gives ↑ ΔT kick.

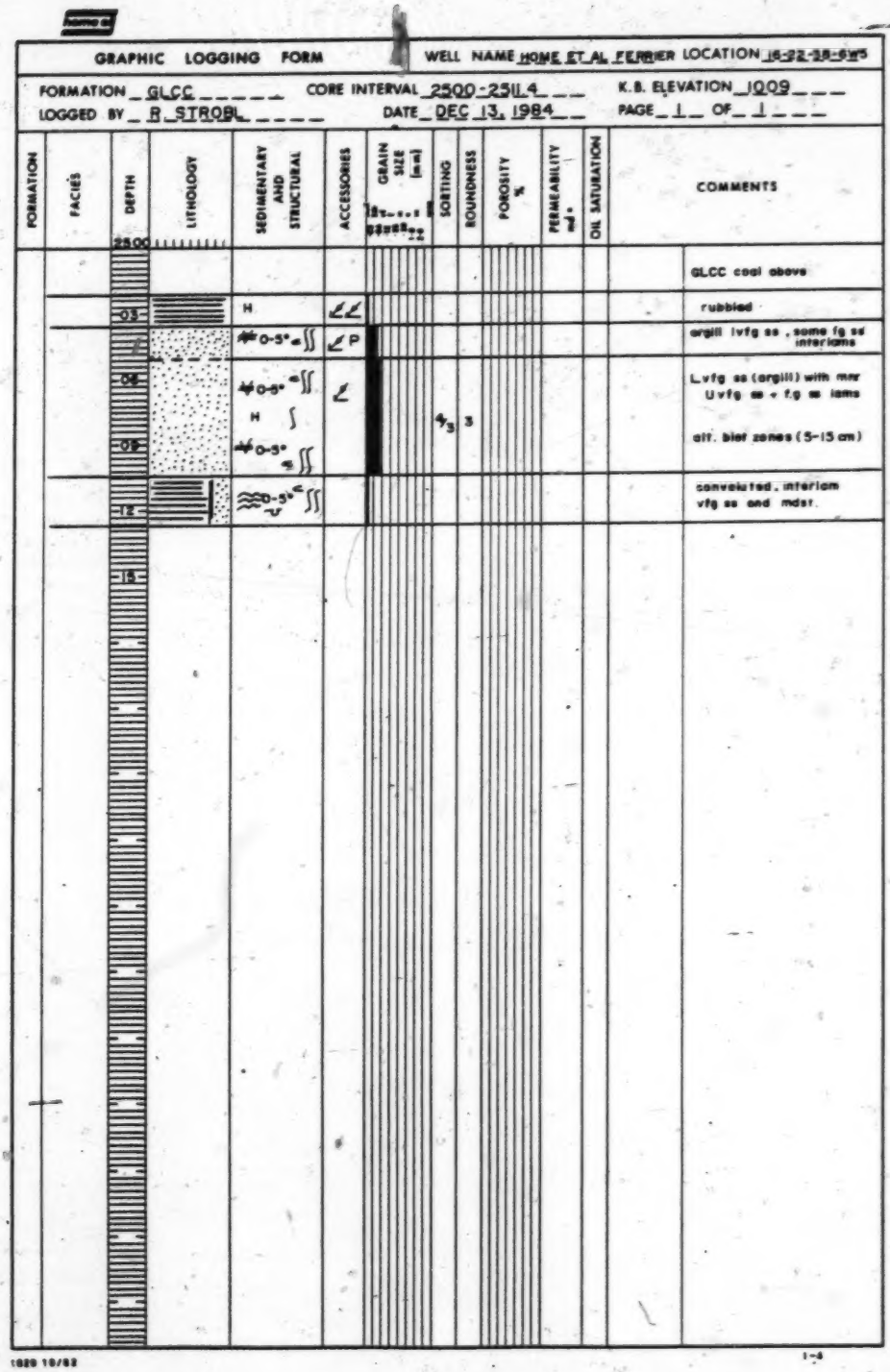
1020 10/82

1-4


GRAPHIC LOGGING FORM
WELL NAME CDN SUP TENS MED R. LOCATION 7-34-39-5 W5
FORMATION GLCC
CORE INTERVAL 7210-7270
K.B. ELEVATION 3161 Ft
LOGGED BY R. STROBL
DATE Jan 10/85
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md
OIL SATURATION
COMMENTS
7200
Sample no.
disturbed beds
0-10°
sandy beds occur at Δ T. ↑ kicks
mnr sideritic concretions throughout (4-10 cm)
silty beds occur
vfg ss with contorted and disturbed bedding
- biot mdst interlams
- microfaulted (slump structures?)
- disc accured beds
mnr interlam vfg ss and mdst beds occur as alternating zones
- disturbed by bioturb and microfaulting

1020 10/83


GRAPHIC LOGGING FORM
WELL NAME Apache Evergreen
LOCATION 10-35-38-4W5
FORMATION GLCC
CORE INTERVAL 7186 - 7205
K.B. ELEVATION 3182
LOGGED BY R. STROBL
DATE Jan 10/85
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md.
OIL SATURATION
COMMENTS
7180
Sample no.
1
2
3
90
H
os
H
os
7200
10
(Not depth corrected)
- minor siderific concretions throughout
- sandy beds disturbed by bioturb
1020 10/82
1-4



GRAPHIC LOGGING FORM

WELL NAME HOME ET AL FERRIER LOCATION 16-22-38-6W5

FORMATION GLCC CORE INTERVAL 2500-2514 K.B. ELEVATION 1009

LOGGED BY R. STROBL DATE DEC 13, 1984 PAGE 1 OF 1

FORMATION | FACIES | DEPTH | LITHOLOGY | SEDIMENTARY AND STRUCTURAL | ACCESSORIES | GRAIN SIZE (mm) | SORTING | ROUNDNESS | POROSITY % | PERMEABILITY md. | OIL SATURATION | COMMENTS

2500

GLCC coal above

rubbled

argill lvfg ss, some fg ss interlams

L vfg ss (argill) with mm U vfg ss + fg ss lams

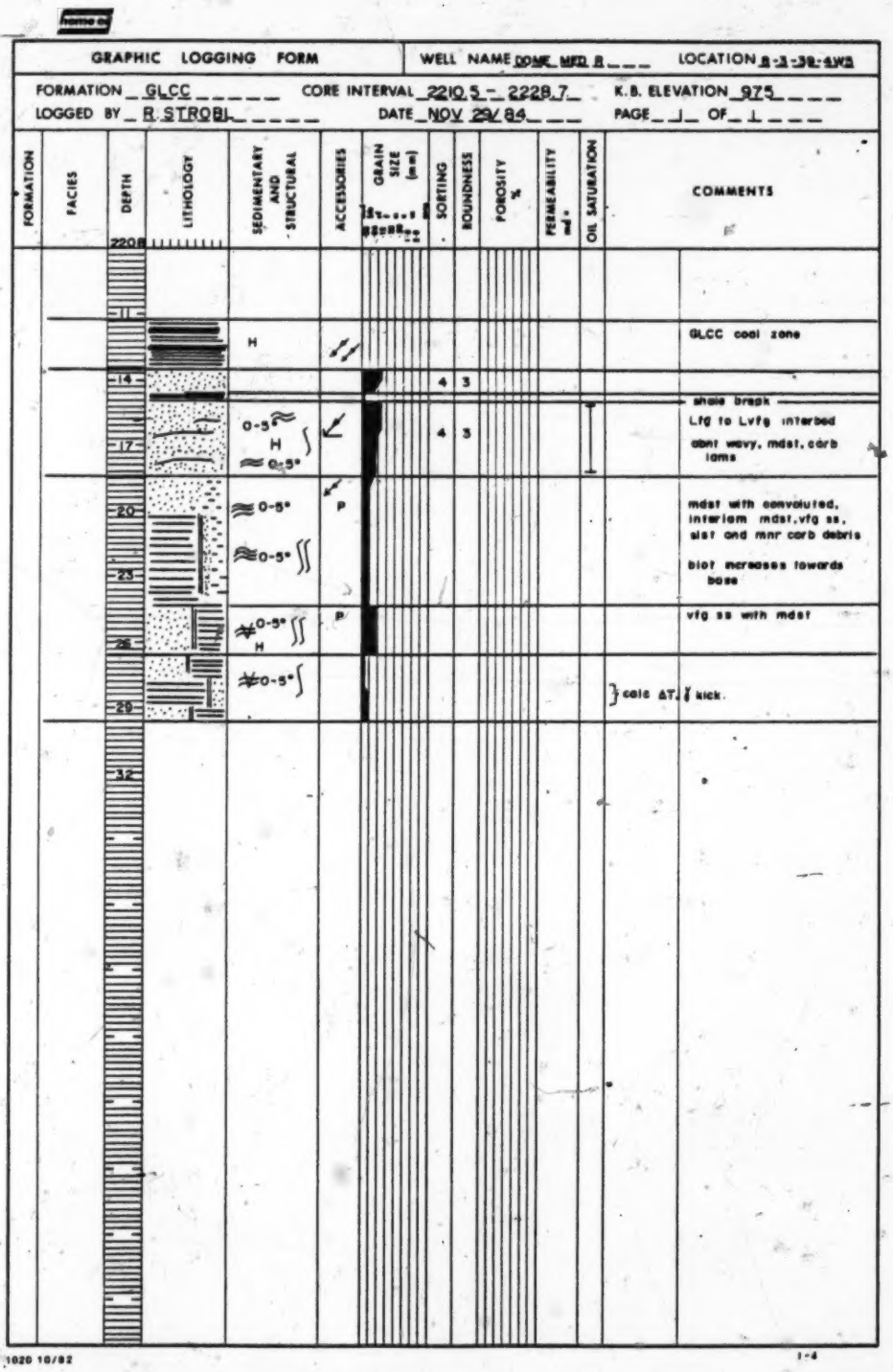
alt. biot zones (5-15 cm)

convoluted, interlam vfg ss and mdst.

2515

1029 10/83

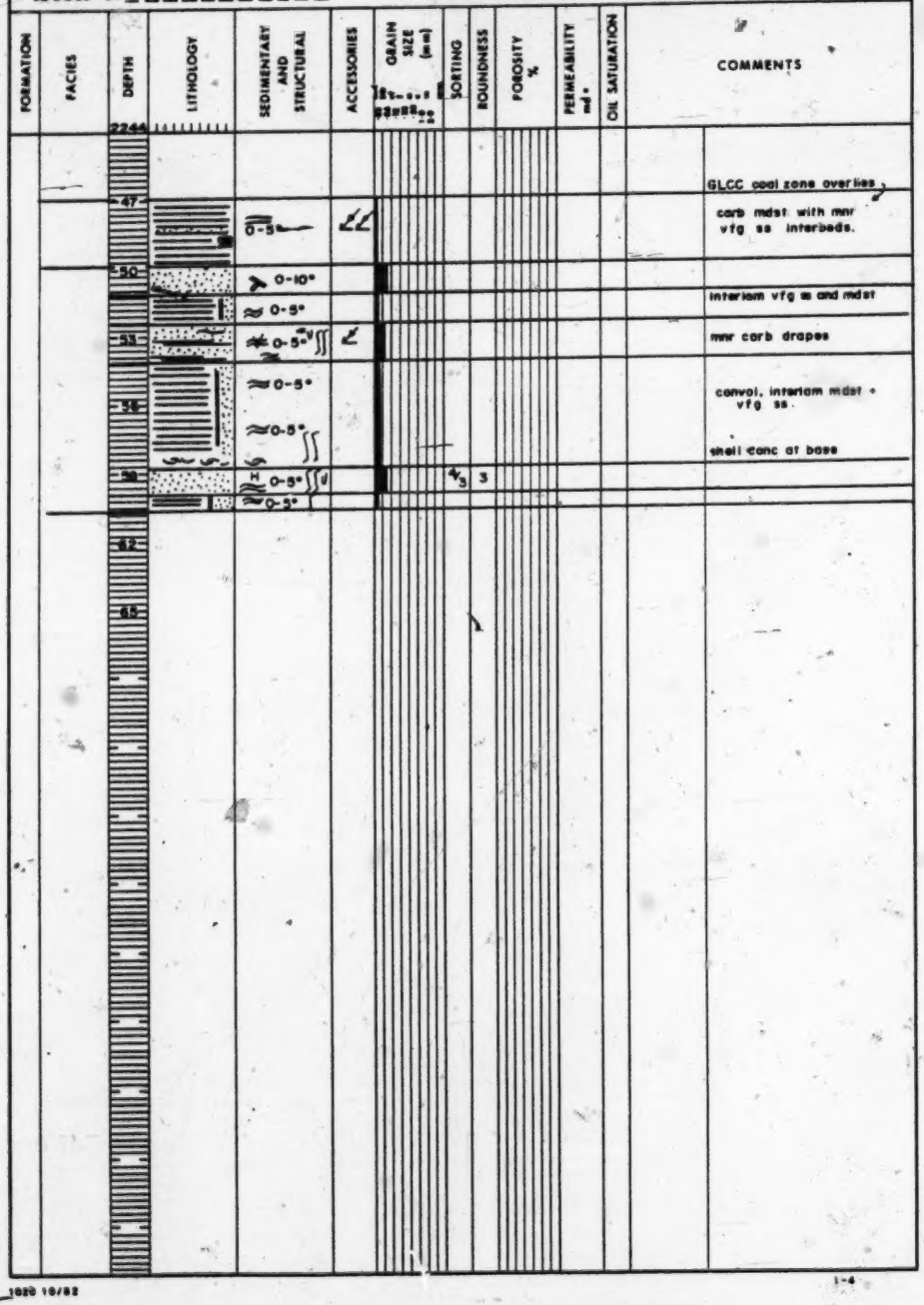
1-6


GRAPHIC LOGGING FORM
WELL NAME DOME MED 8
LOCATION 8-3-38-4W3
FORMATION GLCC
CORE INTERVAL 2210.5 - 2228.7
K.B. ELEVATION 975
LOGGED BY R. STROBL
DATE NOV 29/84
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md
OIL SATURATION
COMMENTS
2208
11
14
17
20
23
26
29
32
H
0-5°
P
GLCC coal zone
4
3
shale break
Lfg to Lvfg interbed
abnt wavy, mdst, carb lams
mdst with convoluted, interlam mdst, vfg ss, slst and mnr carb debris
biot increases towards base
vfg ss with mdst
coals ΔT, ↓ kick.

GRAPHIC LOGGING FORM — WELL NAME SUN MED. R. — LOCATION 12-3-38-4W5

FORMATION GLCC — CORE INTERVAL 2247.5 - 2261.5 — K.B. ELEVATION 971.8

LOGGED BY R. STROBL — DATE NOV. 29/84 — PAGE 1 OF 1



1020 10/82

1-4

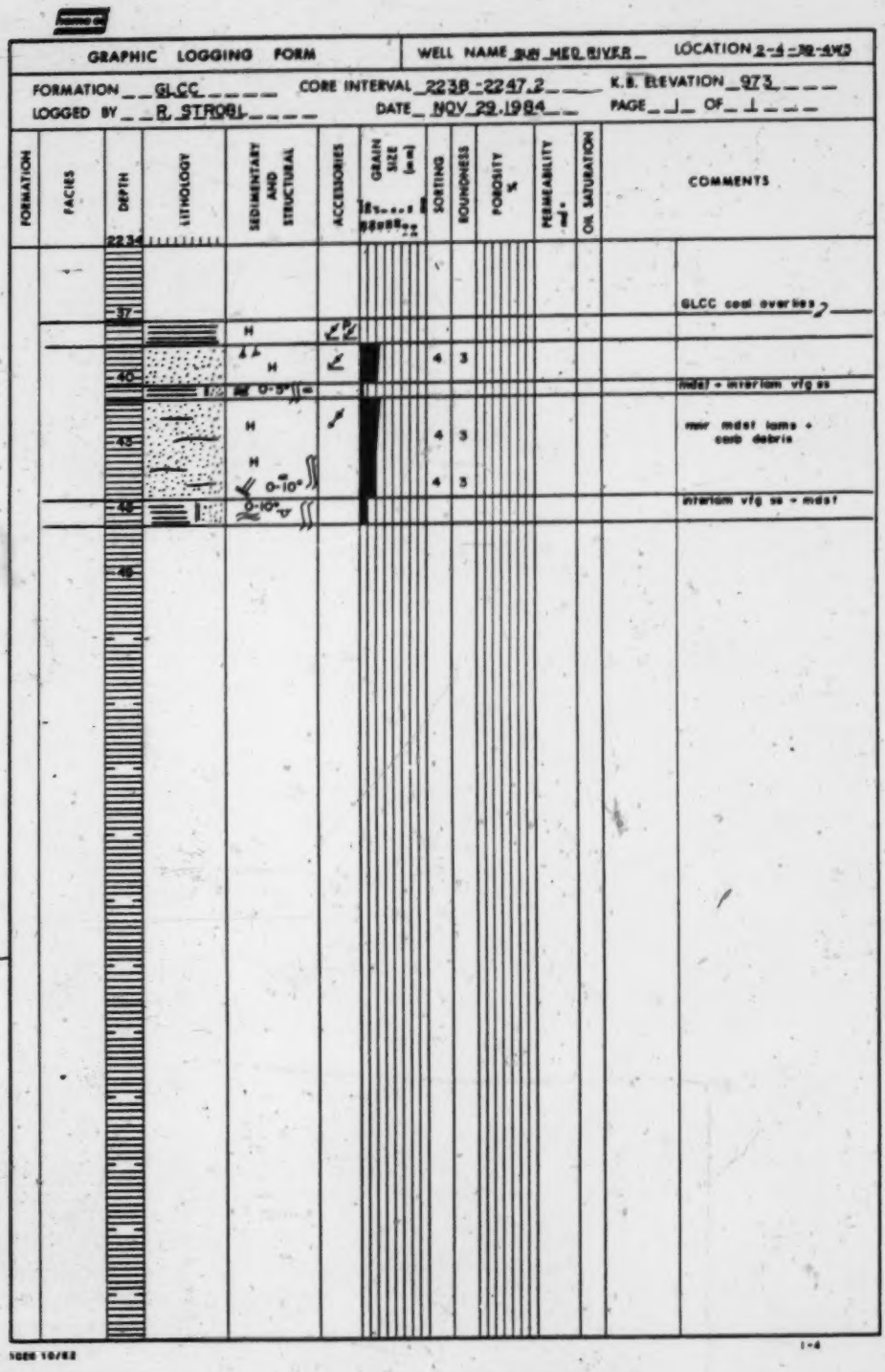
GRAPHIC LOGGING FORM — WELL NAME DOME MED RIVER — LOCATION 10-3-39-4W5

FORMATION GLCC — CORE INTERVAL 2207-2217 — K.B. ELEVATION 974

LOGGED BY R. STROBL — DATE NOV 29/84 — PAGE 1 OF 1

FORMATION	FACIES	DEPTH	LITHOLOGY	SEDIMENTARY AND STRUCTURAL	ACCESSORIES	GRAIN SIZE (mm)	SORTING	ROUNDNESS	POROSITY %	PERMEABILITY md	OIL SATURATION	COMMENTS
		2203										
		06		0-5° H	P							GLCC coal zone minor vfg ss lenses throughout.
		09					4	3				mnr mdst + carb lams
		12		0-5° NR			4	3				slt Uvfg ss (saturated) well lam with bioturb Lvfg ss, massive + unsaturated
		15		0-5°			4	3				
		18										

1020 10/82

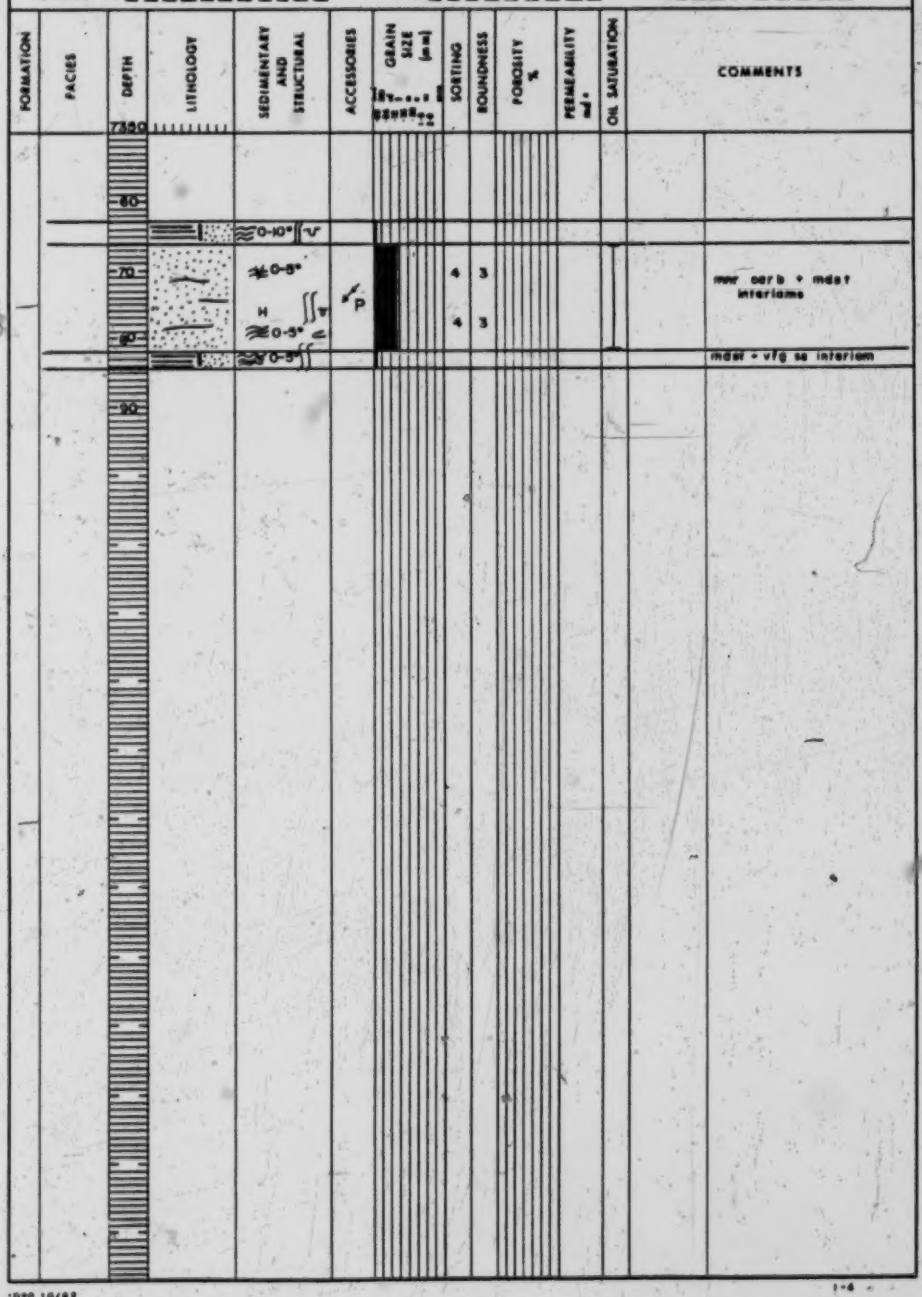

GRAPHIC LOGGING FORM
WELL NAME RED RIVER
LOCATION 2-4-38-4W3
FORMATION GLCC
CORE INTERVAL 2238-2247.2
K.B. ELEVATION 973
LOGGED BY R. STROBL
DATE NOV 29 1984
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md
OIL SATURATION
COMMENTS
2234
37
40
45
48
49
H
0-5°
0-10°
4
3
GLCC coal overlies ?
mdst + interlam vfg ss
mnr mdst lams + comb debris
interlam vfg ss + mdst

GRAPHIC LOGGING FORM

WELL NAME BRUNS CONDOR MED R. LOCATION 6-8-38-4W5

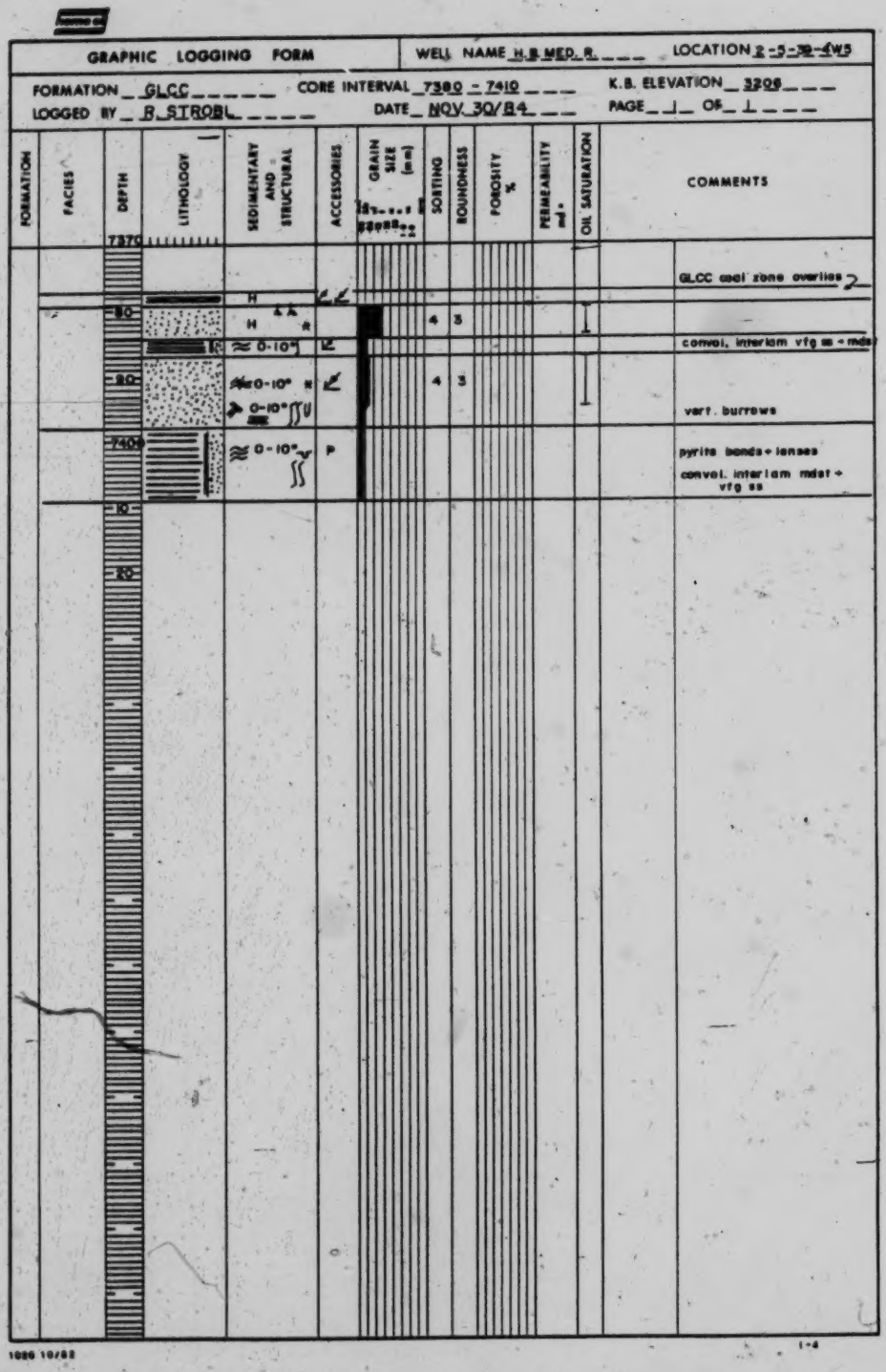
FORMATION GLCC CORE INTERVAL 7360 - 7380 K.B. ELEVATION 3192

LOGGED BY R. STROBL DATE NOV 29/84 PAGE 1 OF 1



1980 10/82

1-4


GRAPHIC LOGGING FORM
WELL NAME H.B MED. B
LOCATION 2-5-32-4W5
FORMATION GLCC
CORE INTERVAL 7380 - 7410
K.B. ELEVATION 3209
LOGGED BY R. STROBL
DATE NOV 30/84
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (m m)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md.
OIL SATURATION
COMMENTS
7370
80
90
7400
10
20
GLCC coal zone overlies
convol. interlam vfg ss + mds
vert. burrows
pyrite bands + lenses
convol. interlam mdst + vfg ss
1086 10/82
1-4

GRAPHIC LOGGING FORM — WELL NAME HB MEDICINE B — LOCATION 4-5-38-4W5

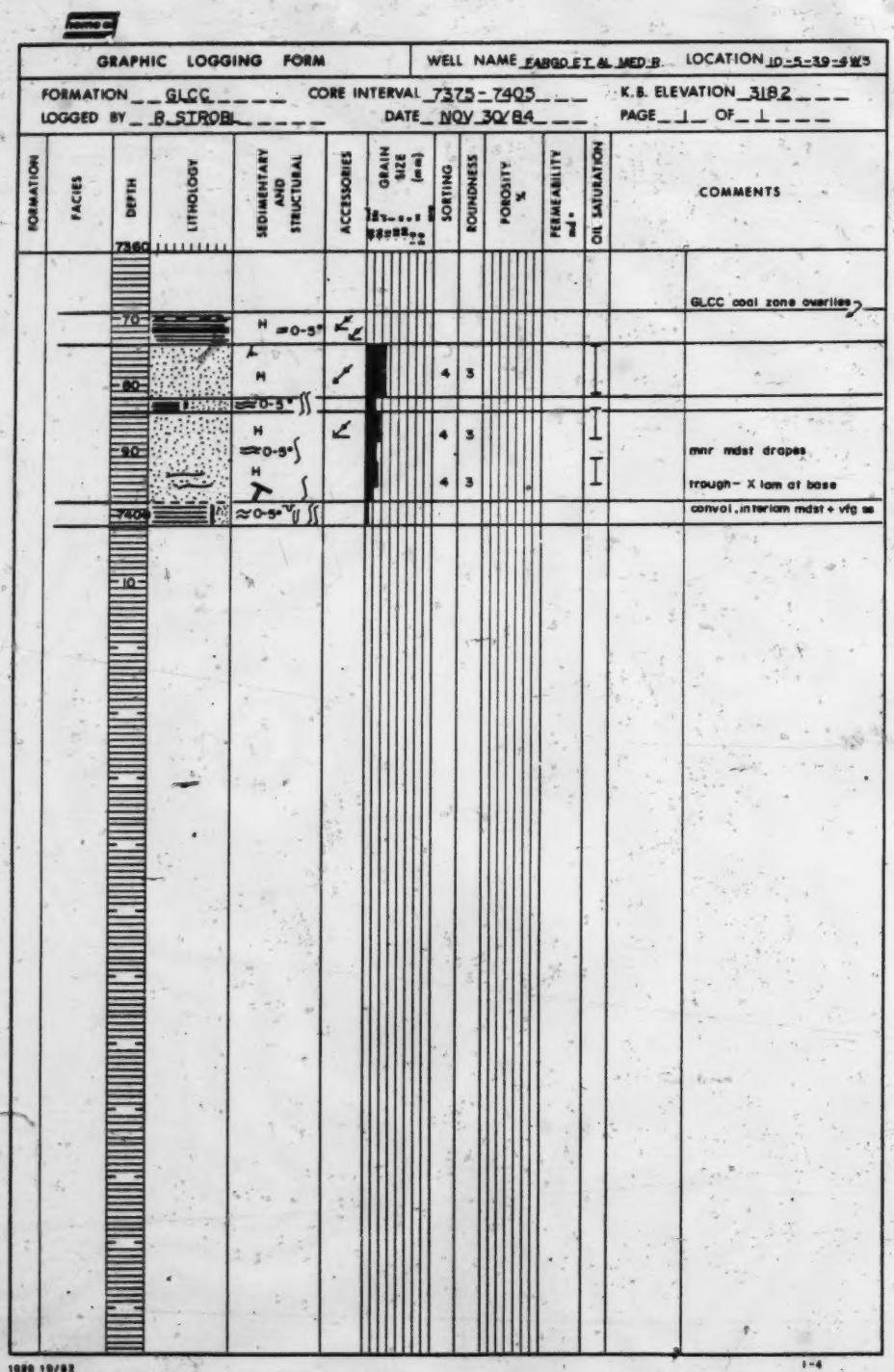
FORMATION GLCC — CORE INTERVAL 7402 - 7437 — K.B. ELEVATION 3189

LOGGED BY R. STROBL — DATE NOV 29/84 — PAGE 1 OF 1

FORMATION	FACIES	DEPTH	LITHOLOGY	SEDIMENTARY AND STRUCTUFAL	ACCESSORIES	GRAIN SIZE (mm)	SORTING	ROUNDNESS	POROSITY %	PERMEABILITY md.	OIL SATURATION	COMMENTS
		7400										
		10		H ≈ 0-5° ∫	*		4	3			I	bioT vfg ss with mdst lams
				≈ 0-10° ∫∫	*		4	3			I	
		20		= 0-10°			1/3	3				mdst and carb drapes
		30		≈ 0-10° ∫∫	P							convol. interlam mdst + vfg ss; vertical burrows; pyrite bands + lenses throughout
		40		≈ 0-10° ∫∫	P							
		50										

1020 10/83

1-4


GRAPHIC LOGGING FORM
WELL NAME FARGO E.T. & MED B LOCATION 10-5-39-9W5
FORMATION GLCC CORE INTERVAL 7375 - 7405 K.B. ELEVATION 3182
LOGGED BY B. STROBL DATE NOV 30/84 PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md
OIL SATURATION
COMMENTS
7360
70
80
90
7400
10
H
≈0-5°
4
3
mnr mdst drapes
trough - X lam at base
convol. interlam mdst + vfg ss
1-4

Form G

GRAPHIC LOGGING FORM — WELL NAME FARGO ET AL MED R. LOCATION 12-3-32-14W3

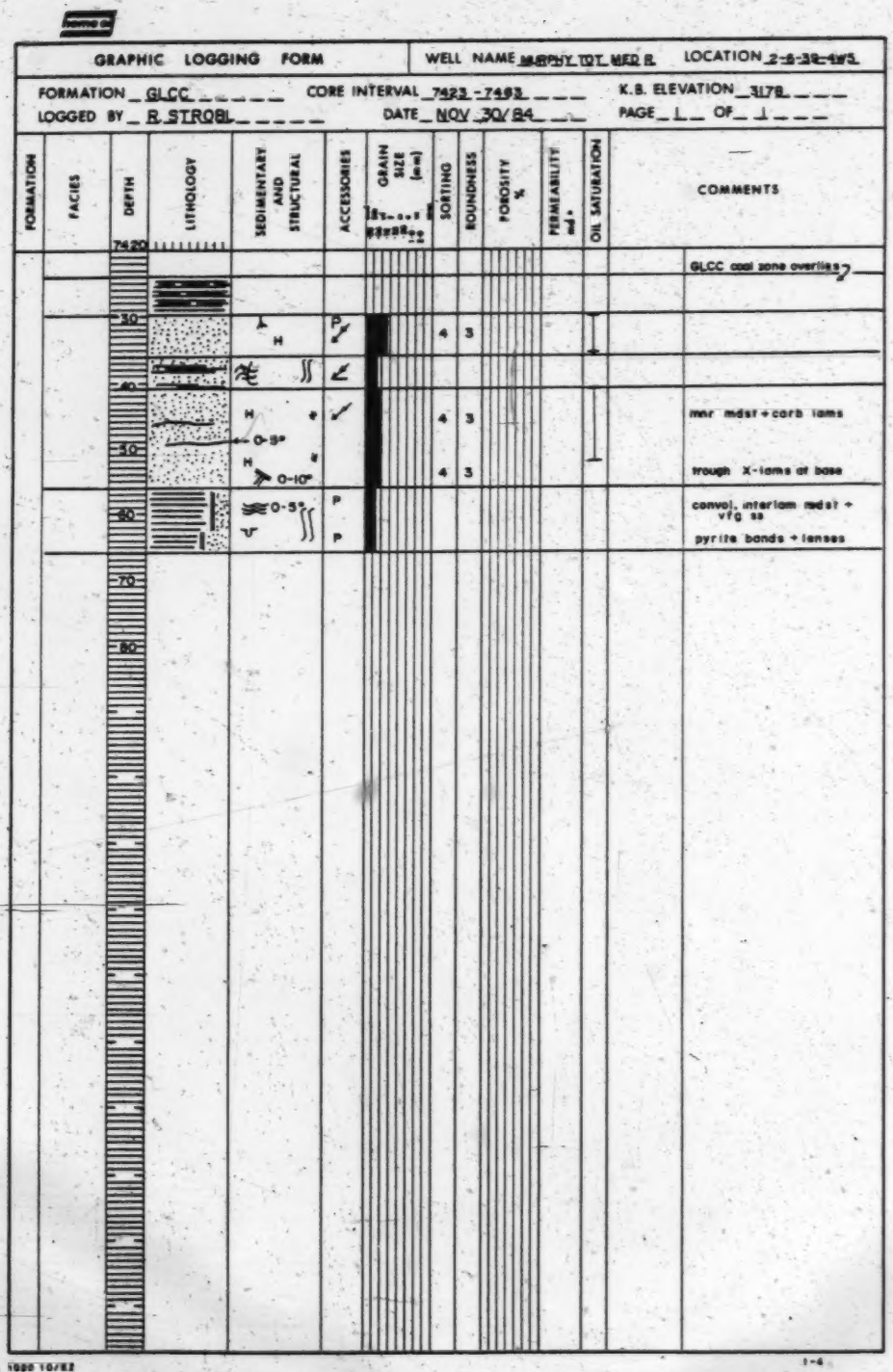
FORMATION GLCC — CORE INTERVAL 7403-7433 — K.B. ELEVATION 3181

LOGGED BY R. STROBL — DATE NOV. 30/84 — PAGE 1 OF 1

FORMATION	FACIES	DEPTH	LITHOLOGY	SEDIMENTARY AND STRUCTURAL	ACCESSORIES	GRAIN SIZE (mm)	SORTING	ROUNDNESS	POROSITY %	PERMEABILITY md	OIL SATURATION	COMMENTS
		7400										GLCC coal zone overlies
		10		H; ≈0-10°			4	3			H	disturbed + biot
		20		H; H; 0-5°			4	3				mnr mdst lams + Lvfg ss bioturbated zones
		30		H			4	3				
		40										
		50										

1020 10/82

1-4


GRAPHIC LOGGING FORM
WELL NAME HARDY TOT. WELL B. LOCATION 2-8-38-4W5
FORMATION GLCC CORE INTERVAL 7423 - 7493 K.B. ELEVATION 3178
LOGGED BY R. STROBL DATE NOV 30/84 PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md.
OIL SATURATION
COMMENTS
7420
30
40
50
60
70
80
0-5°
0-10°
0-5°
4 3
4 3
4 3
GLCC coal zone overlies ?
mnr mdst + carb lams
trough X-lams at base
convol. interlam mdst + vfg ss
pyrite bands + lenses

GRAPHIC LOGGING FORM

WELL NAME TAURUS MURPHY COND LOCATION 10-[illegible]

FORMATION GLCC CORE INTERVAL 7435 - 7473 K.B. ELEVATION 3162

LOGGED BY R. STROBL DATE NOV 30/84 PAGE 1 OF 1

FORMATION	FACIES	DEPTH	LITHOLOGY	SEDIMENTARY AND STRUCTURAL	ACCESSORIES	GRAIN SIZE (mm)	SORTING	ROUNDNESS	POROSITY %	PERMEABILITY md.	OIL SATURATION	COMMENTS
		7440										(lower portion of sheet -ss.)
				H			4	3			X	
		50		0-10°			3/4	3				convol, interlam mdst + vfg ss
				H								
		60		H 0-5° 0-10°			4	3				abnt mdst + carb drapes at base
		70		0-5°								convol, interlam mdst + vfg ss
		80										

1820 10/82

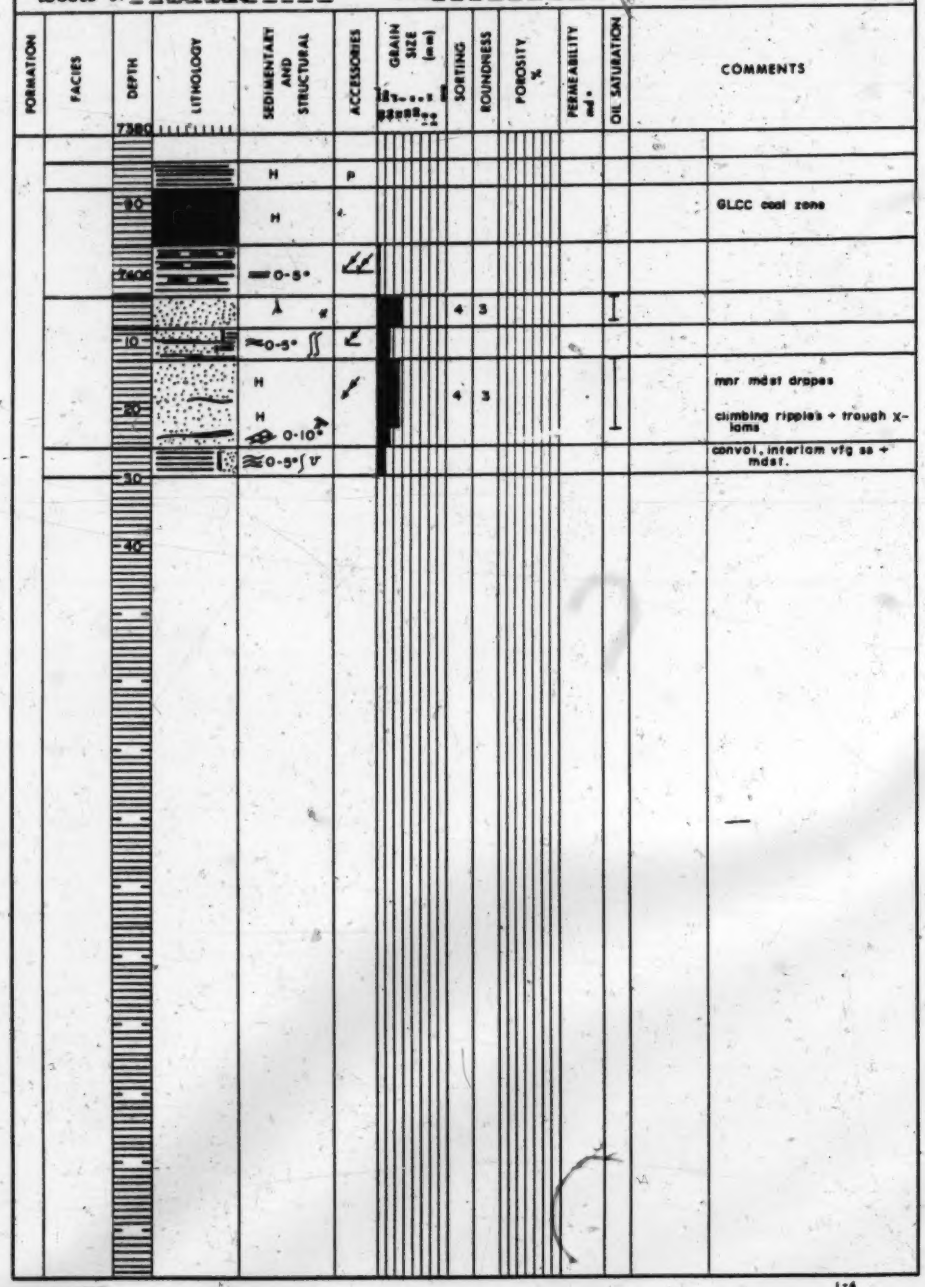
1-6

GRAPHIC LOGGING FORM

WELL NAME MURPHY TOTAL MED R. LOCATION 2-7-38-4W5

FORMATION GLCC CORE INTERVAL 7389-7435 K.B. ELEVATION 3154

LOGGED BY R.STROBL DATE NOV 30/84 PAGE 1 OF 1



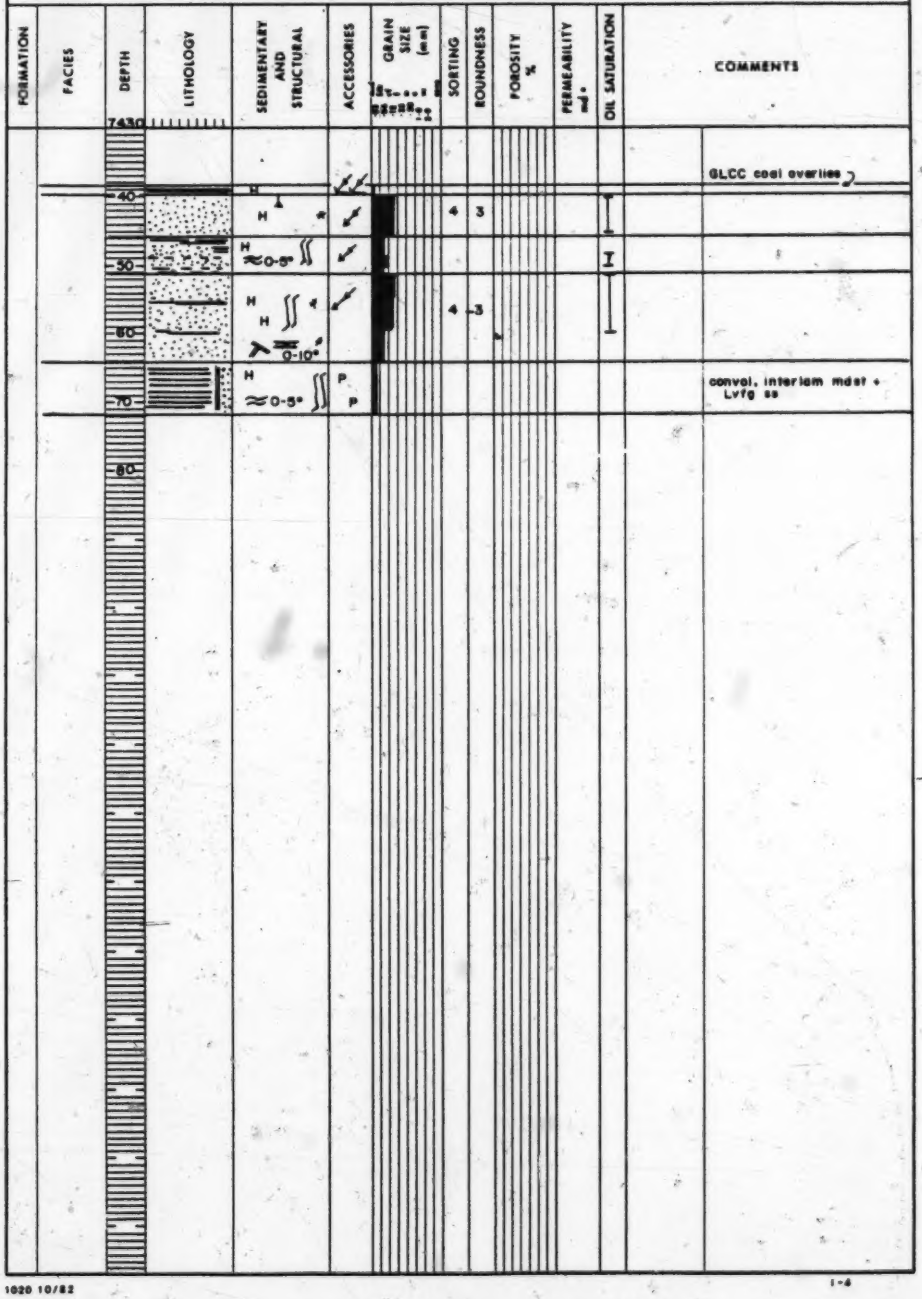
1-4

GRAPHIC LOGGING FORM

WELL NAME TAURUS MURPHY COND LOCATION 9-7-31E-4W2

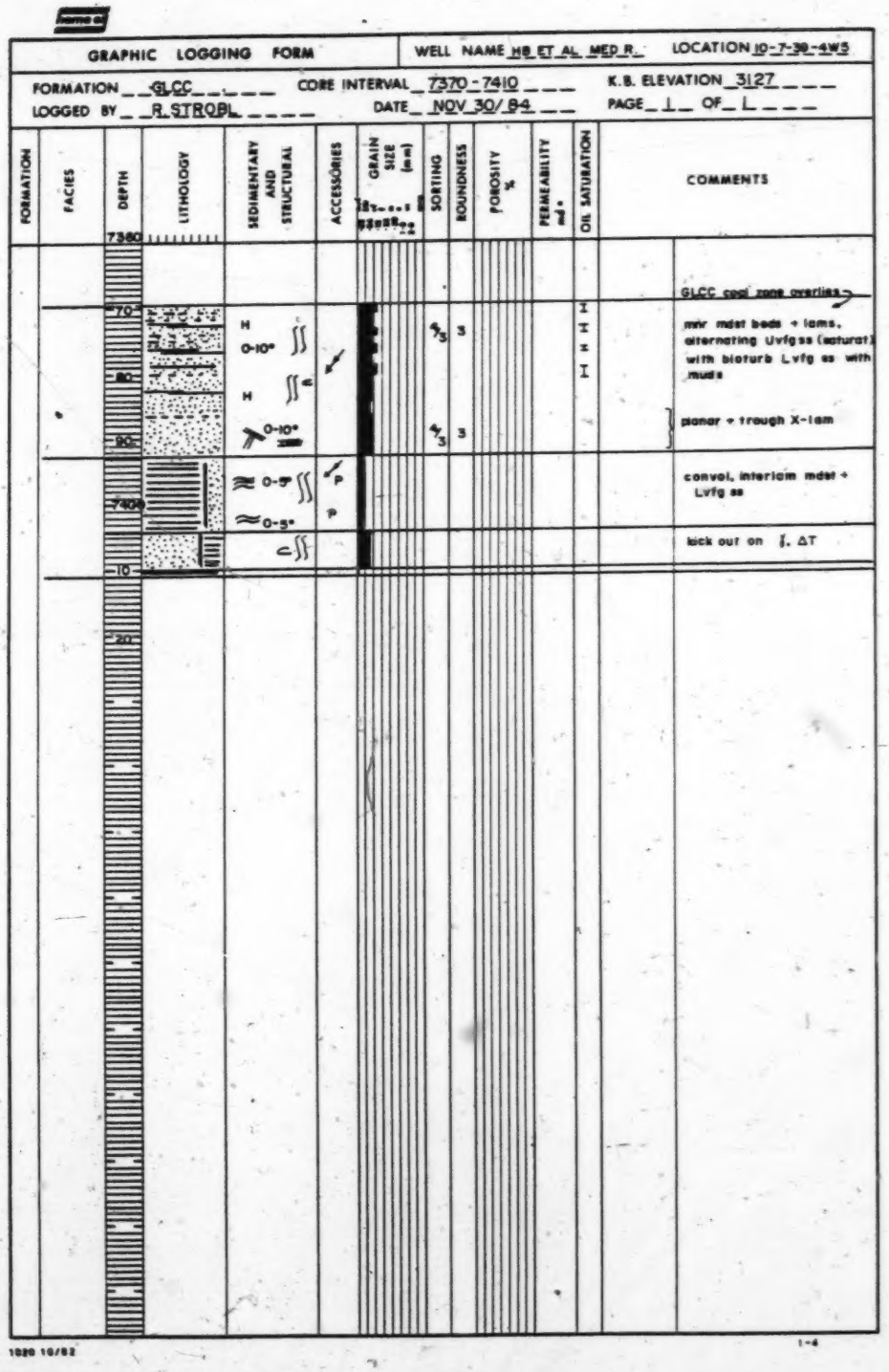
FORMATION GLCC CORE INTERVAL 7435-7470 K.B. ELEVATION 3152

LOGGED BY R. STROBL DATE NOV 30/84 PAGE 1 OF 1



1020 10/82

1-6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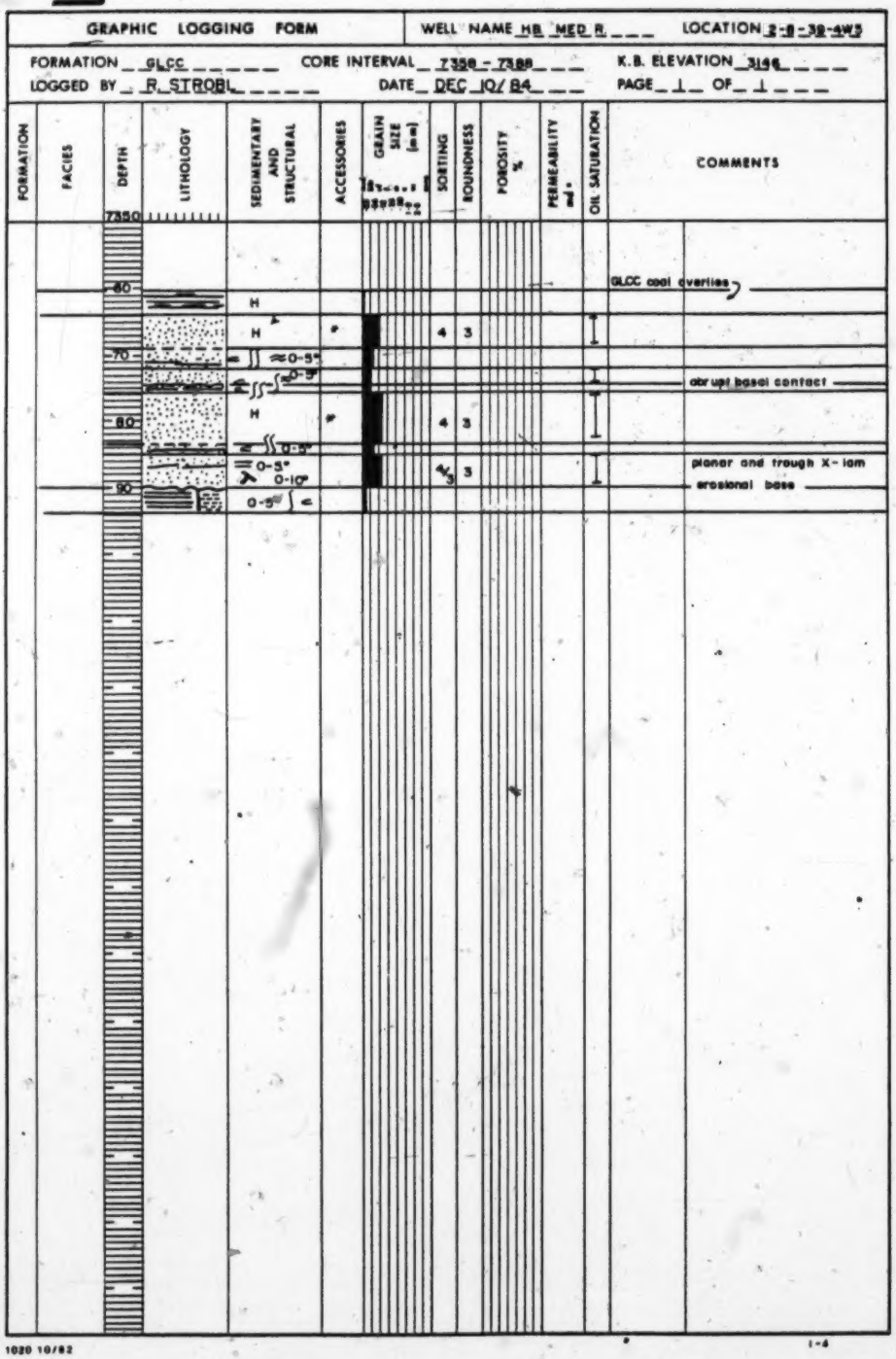
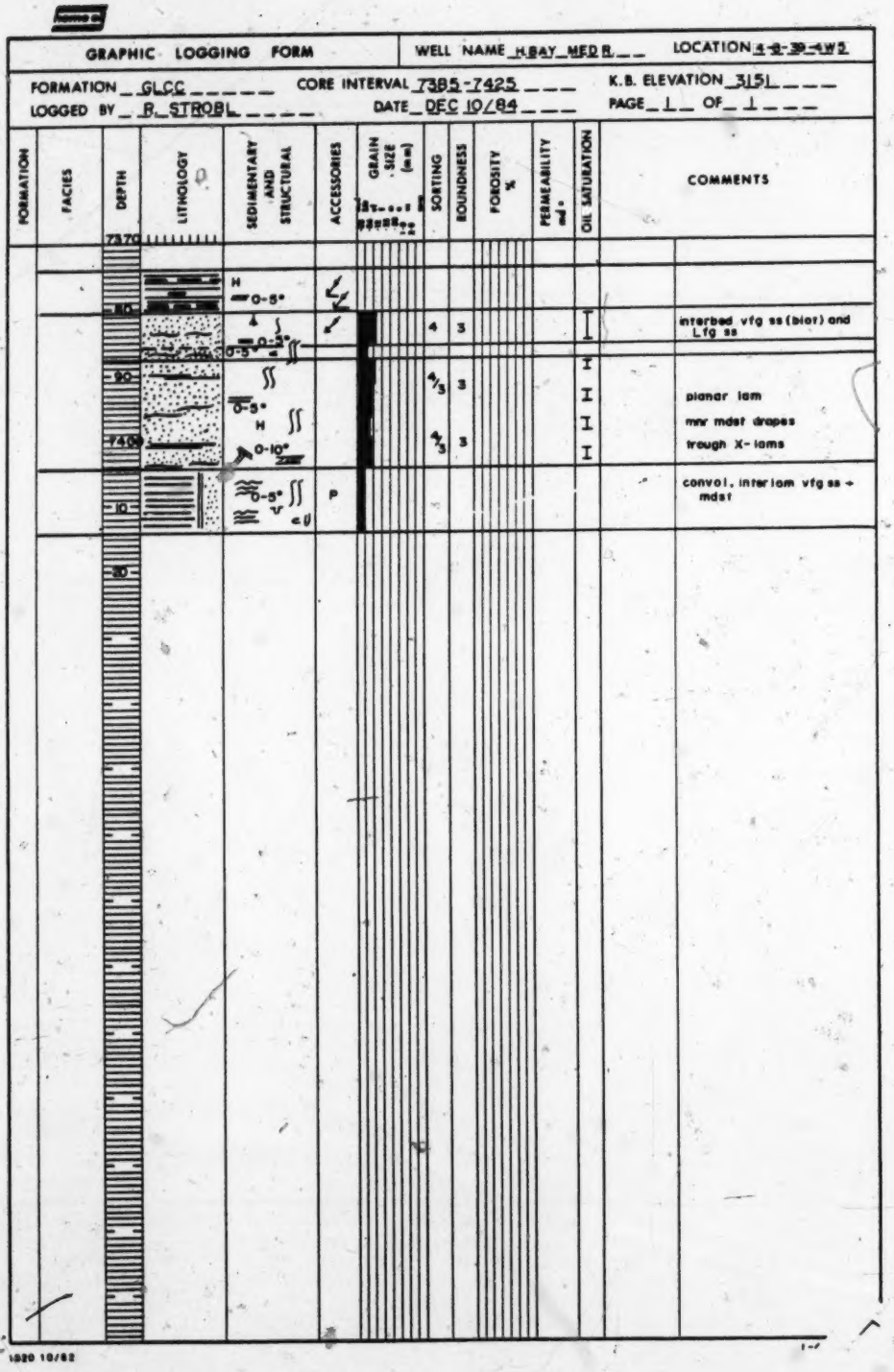
WELL NAME HB ET AL MED R. LOCATION 10-7-30-4W5
FORMATION GLCC
CORE INTERVAL 7370 - 7410
K.B. ELEVATION 3127
LOGGED BY R. STROBL
DATE NOV 30/84
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md
OIL SATURATION
COMMENTS
7360
70
80
90
7400
10
20
GLCC coal zone overlies
mlv mdst beds + lams, alternating Uvfgss (saturat) with bioturb Lvfg ss with muds
planar + trough X-lam
convol, interlam mdst + Lvfg ss
lack out on ∫. ΔT
H
0-10°
0-5°
P
S
3
1020 10/82
1-4


GRAPHIC LOGGING FORM
WELL NAME HB MED R
LOCATION 2-8-38-4W5
FORMATION GLCC
CORE INTERVAL 7350 - 7389
K.B. ELEVATION 3196
LOGGED BY R. STROBL
DATE DEC 10/84
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md.
OIL SATURATION
COMMENTS
7350
60
70
80
90
H
≈0-5°
0-5°
0-10°
4
3
GLCC coal overlies
abrupt basal contact
planer and trough X-lam
erosional base

1020 10/82

1-4



GRAPHIC LOGGING FORM

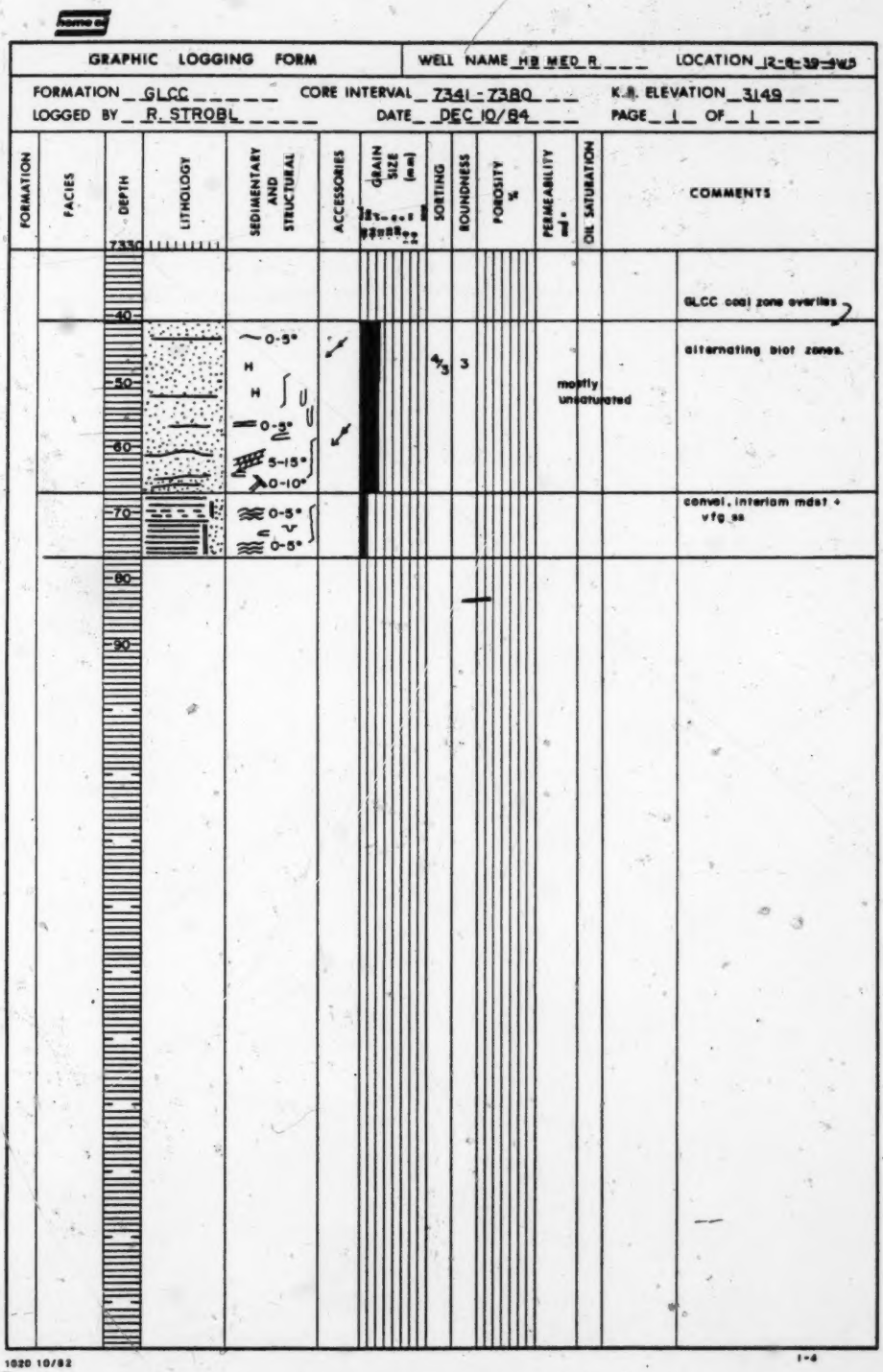
WELL NAME H BAY MED B LOCATION 4-8-39-4W2

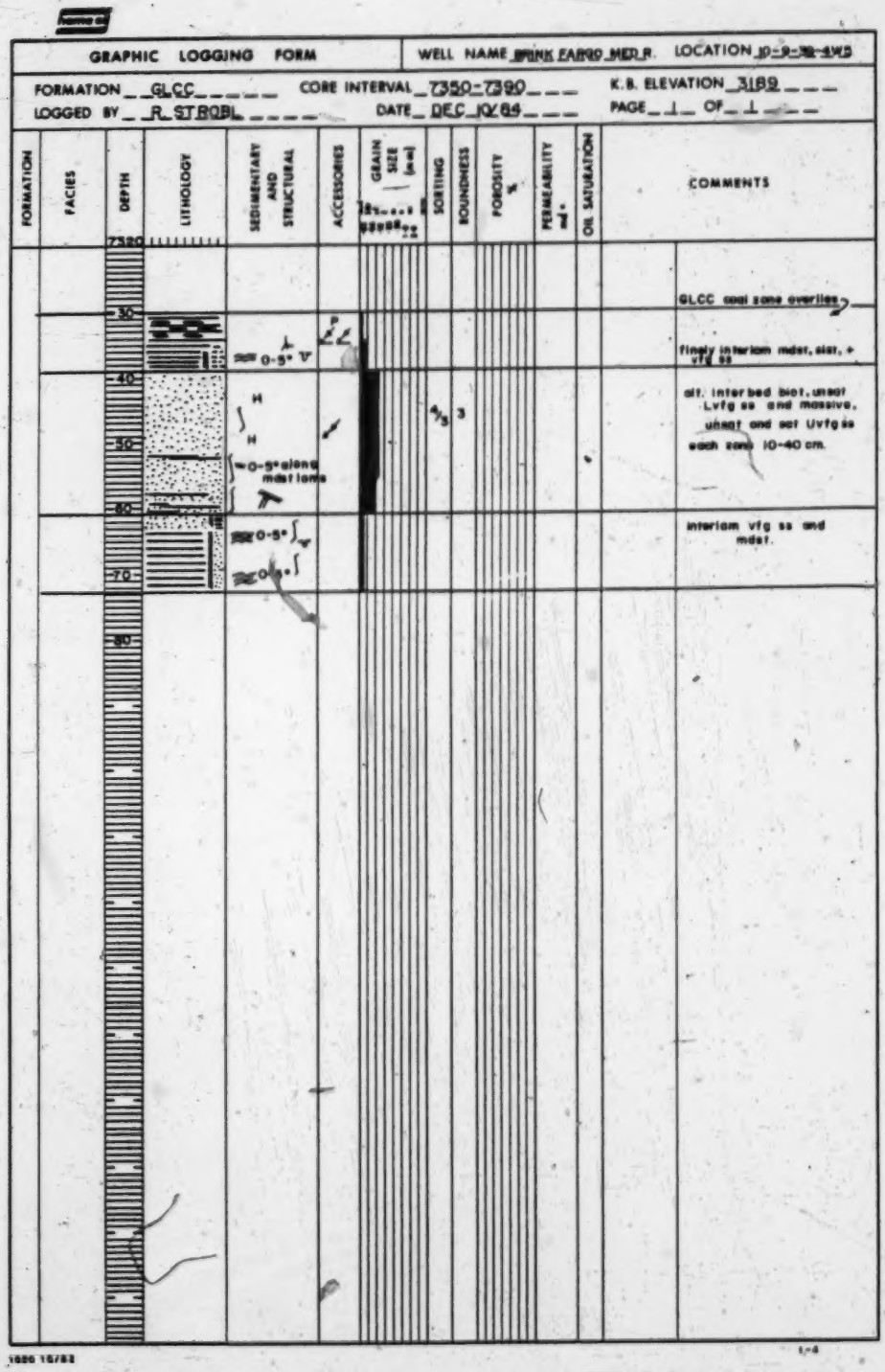
FORMATION GLCC CORE INTERVAL 7385-7425 K.B. ELEVATION 3151

LOGGED BY R. STROBL DATE DEC 10/84 PAGE 1 OF 1

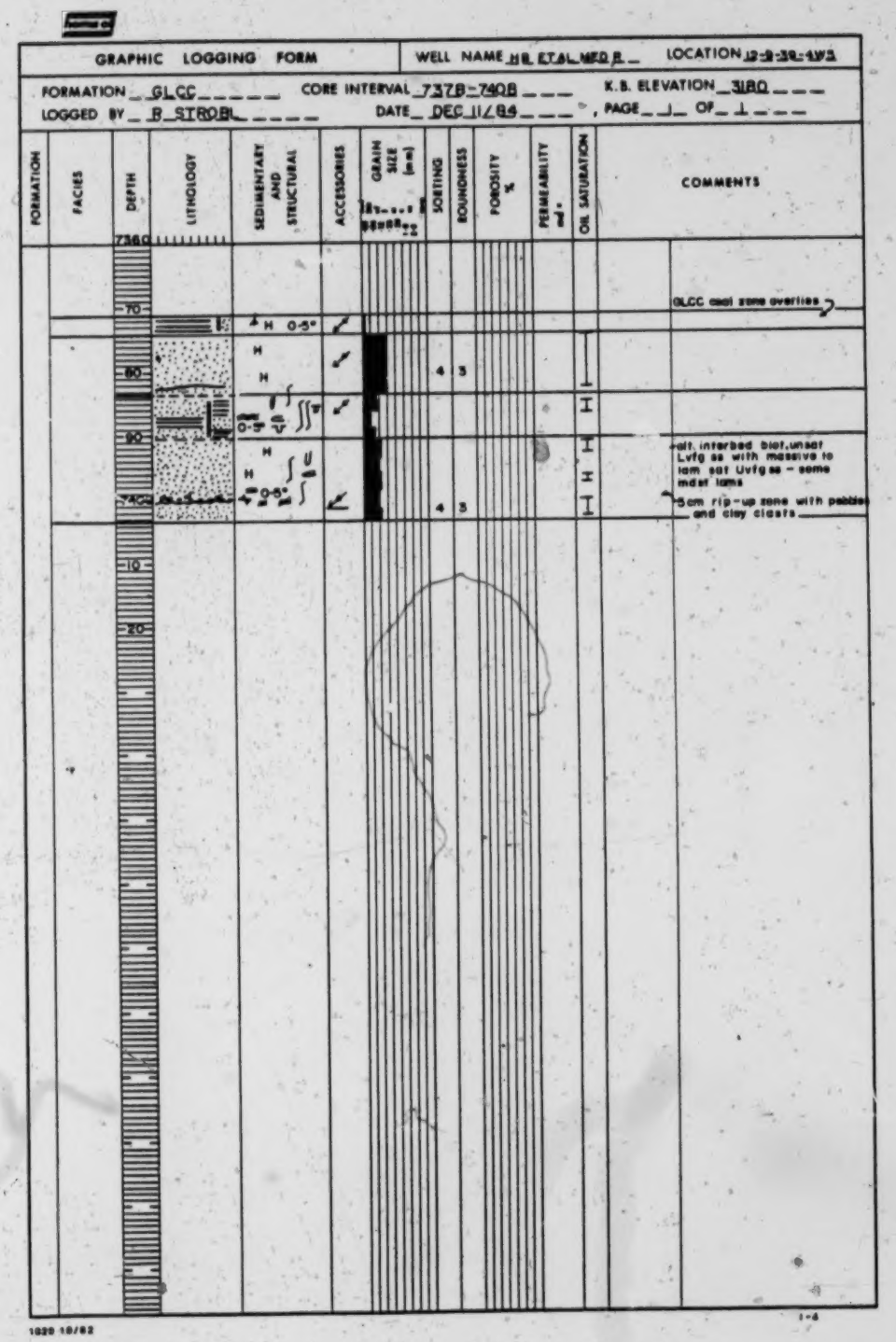
FORMATION	FACIES	DEPTH	LITHOLOGY	SEDIMENTARY AND STRUCTURAL	ACCESSORIES	GRAIN SIZE (mm)	SORTING	ROUNDNESS	POROSITY %	PERMEABILITY md.	OIL SATURATION	COMMENTS
		7370										
				H 0-5°								
		80		0-5° 0-5°			4	3			I	interbed vfg ss (biot) and Lfg ss
		90		0-5° H			4/3	3			I I	planar lam mm mdst drapes
		7400		0-10°			4/3	3			I I	trough X-lams
		10		0-5° V	P							convol. interlam vfg ss + mdst
		20										

1920 10/82


GRAPHIC LOGGING FORM
WELL NAME HB MED R
LOCATION 12-8-39-9W5
FORMATION GLCC
CORE INTERVAL 7341 - 7380
K.B. ELEVATION 3149
LOGGED BY R. STROBL
DATE DEC 10/84
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md
OIL SATURATION
COMMENTS
7330
40
50
60
70
80
90
0-5°
0-5°
5-15°
0-10°
0-5°
0-5°
4/3
3
mostly unsaturated
GLCC coal zone overlies
alternating biot zones.
convol. interlam mdst + vfg ss
1020 10/82
1-4


GRAPHIC LOGGING FORM
WELL NAME BRINK FARMS MED. R. LOCATION 10-9-38-4W5
FORMATION GLCC
CORE INTERVAL 7350-7390
K.B. ELEVATION 3189
LOGGED BY R STROBL
DATE DEC 10 84
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md.
OIL SATURATION
COMMENTS
7320
30
40
50
60
70
80
0-5° V
H
H
0-5° along mottles
0-5°
0-5°
GLCC coal zone overlies
finely interlam mdst, slst, + vfg ss
slt. interbed biot. unsrt Lvfg ss and massive, unsrt and sct Uvfg ss each zone 10-40 cm.
3/3
3
interlam vfg ss and mdst.

1886 15/83


GRAPHIC LOGGING FORM
WELL NAME HB ET AL MED R
LOCATION 12-8-38-4W5
FORMATION GLCC
CORE INTERVAL 7378-7408
K.B. ELEVATION 3180
LOGGED BY B STROBL
DATE DEC 11/84
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md
OIL SATURATION
COMMENTS
7360
70
80
90
7400
10
20
GLCC coal zone overlies
H 0-5°
4 3
0-5°
4 3
calc. interbed biot.unsct Lvfg ss with massive to lam sst Uvfg ss - some mdst lams
5cm rip-up zone with pebble and clay clasts
1029 10/82
1-4

GRAPHIC LOGGING FORM

WELL NAME BRINK CONOCO MED R. LOCATION 4-10-38-4W5

FORMATION GLCC CORE INTERVAL 7360-7387 K.B. ELEVATION 3208

LOGGED BY R. STROBL DATE DEC 11/84 PAGE 1 OF 1

FORMATION	FACIES	DEPTH	LITHOLOGY	SEDIMENTARY AND STRUCTURAL	ACCESSORIES	GRAIN SIZE (mm)	SORTING	ROUNDNESS	POROSITY %	PERMEABILITY md.	OIL SATURATION	COMMENTS
		7360		0-5°								GLCC coal zone overlies
		70		0-5°			4	3				mnr mdst lams
				0-5°								
		80		0-5° H			4/3	3				
				0-5° 0-10°								
		90										
		7400										

1685 10/82

1-4

HB GLAUC A POOL

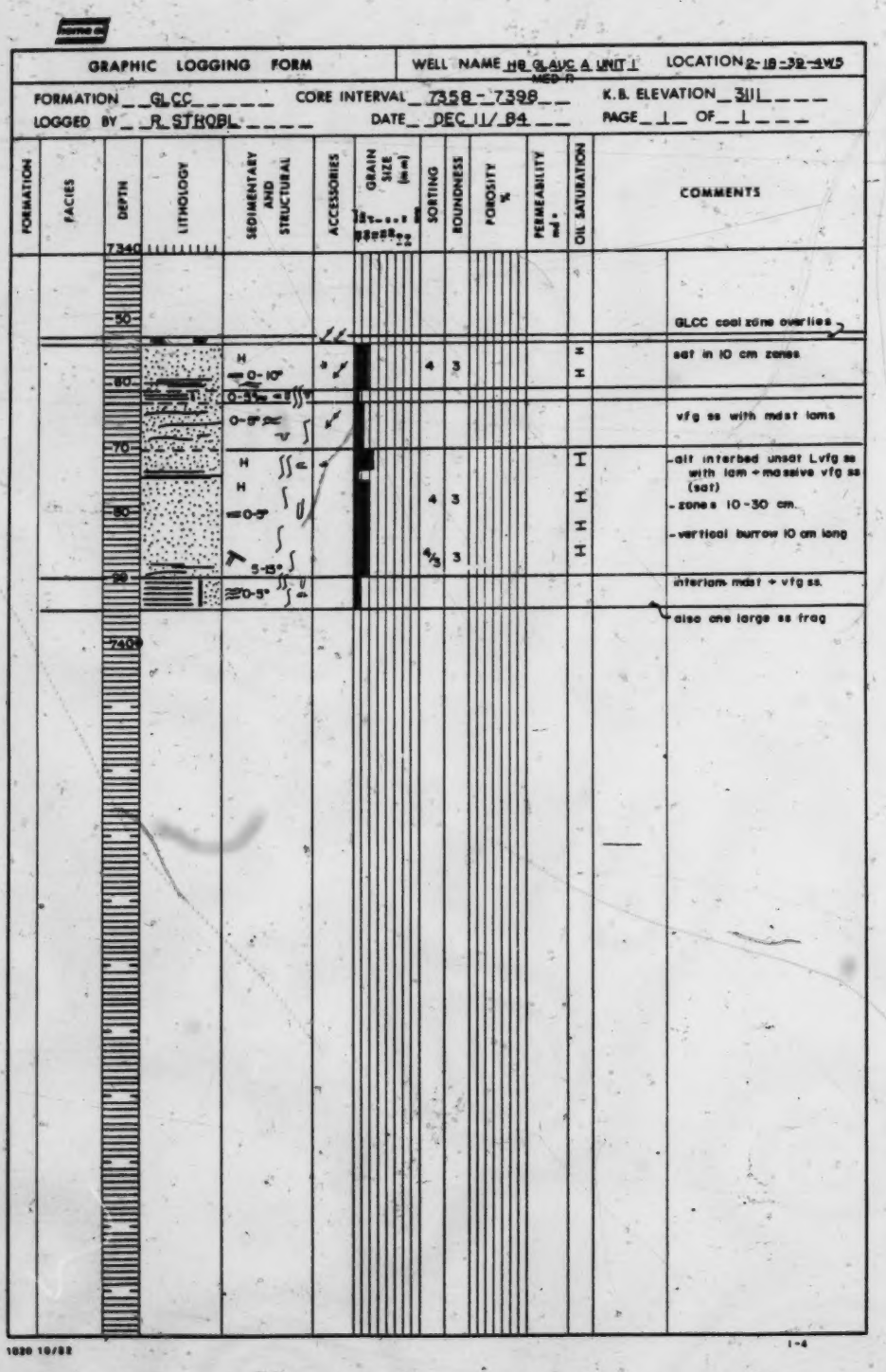
GRAPHIC LOGGING FORM — WELL NAME UNIT MED R. — LOCATION 12-17-39-4W5

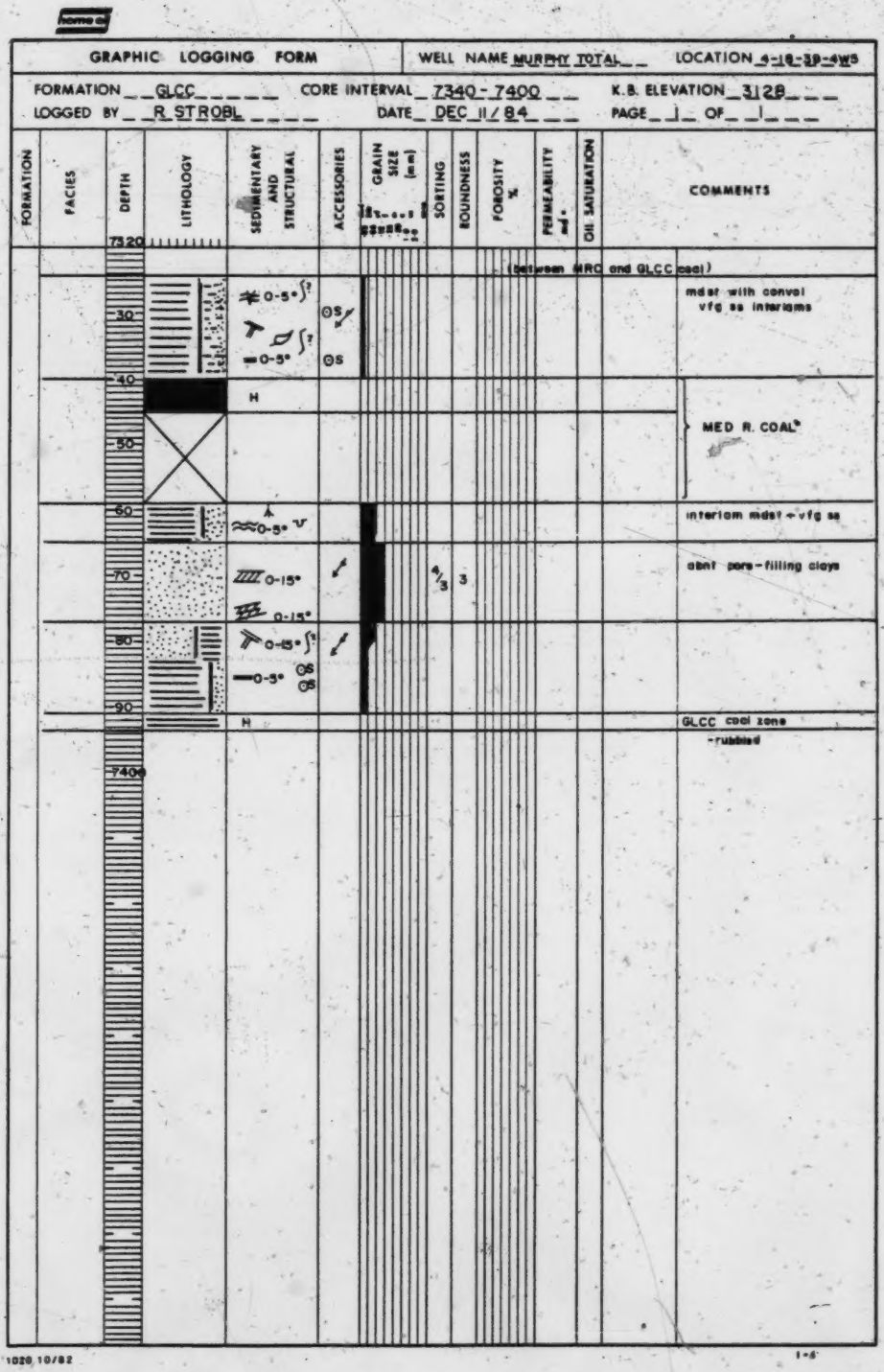
FORMATION GLCC — CORE INTERVAL 7298 - 7338 — K.B. ELEVATION 3113

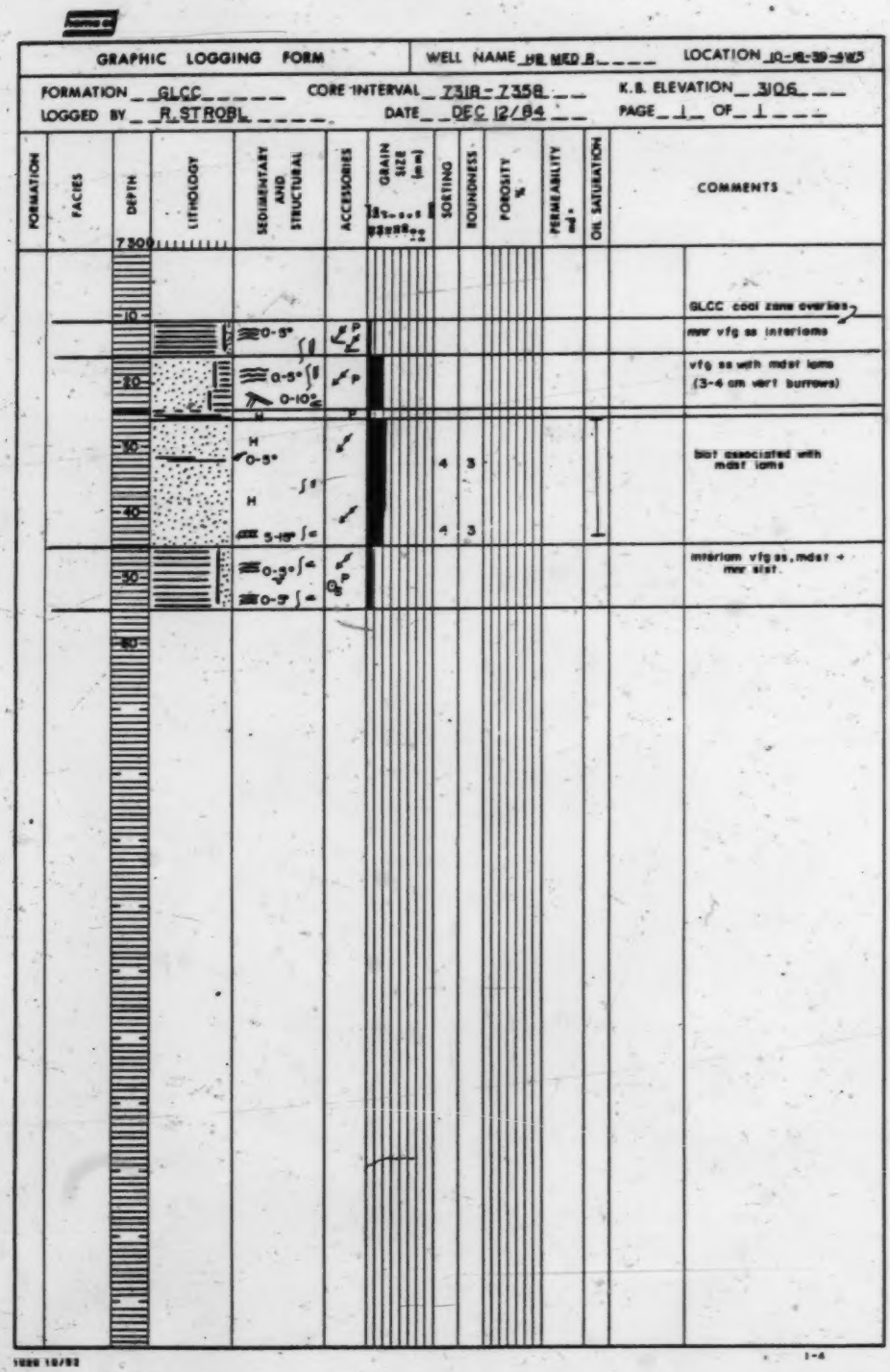
LOGGED BY R STROBL — DATE DEC 11/84 — PAGE 1 OF 1

FORMATION	FACIES	DEPTH	LITHOLOGY	SEDIMENTARY AND STRUCTURAL	ACCESSORIES	GRAIN SIZE (mm)	SORTING	ROUNDNESS	POROSITY %	PERMEABILITY md	OIL SATURATION	COMMENTS
		7290										GLCC coal zone overlies
		7300		H 0-5° M								
		10		0-10° H 0-5°	P		3/3	3				
		20		H H 0-5° V	P		3/3	3			I N I	oil interbed, bioturb unsat L vfg ss with some mdst lams and Uvfg massive ss
		40		0-5° V U	P							convol. interlam mdst + vfg ss.
		50										

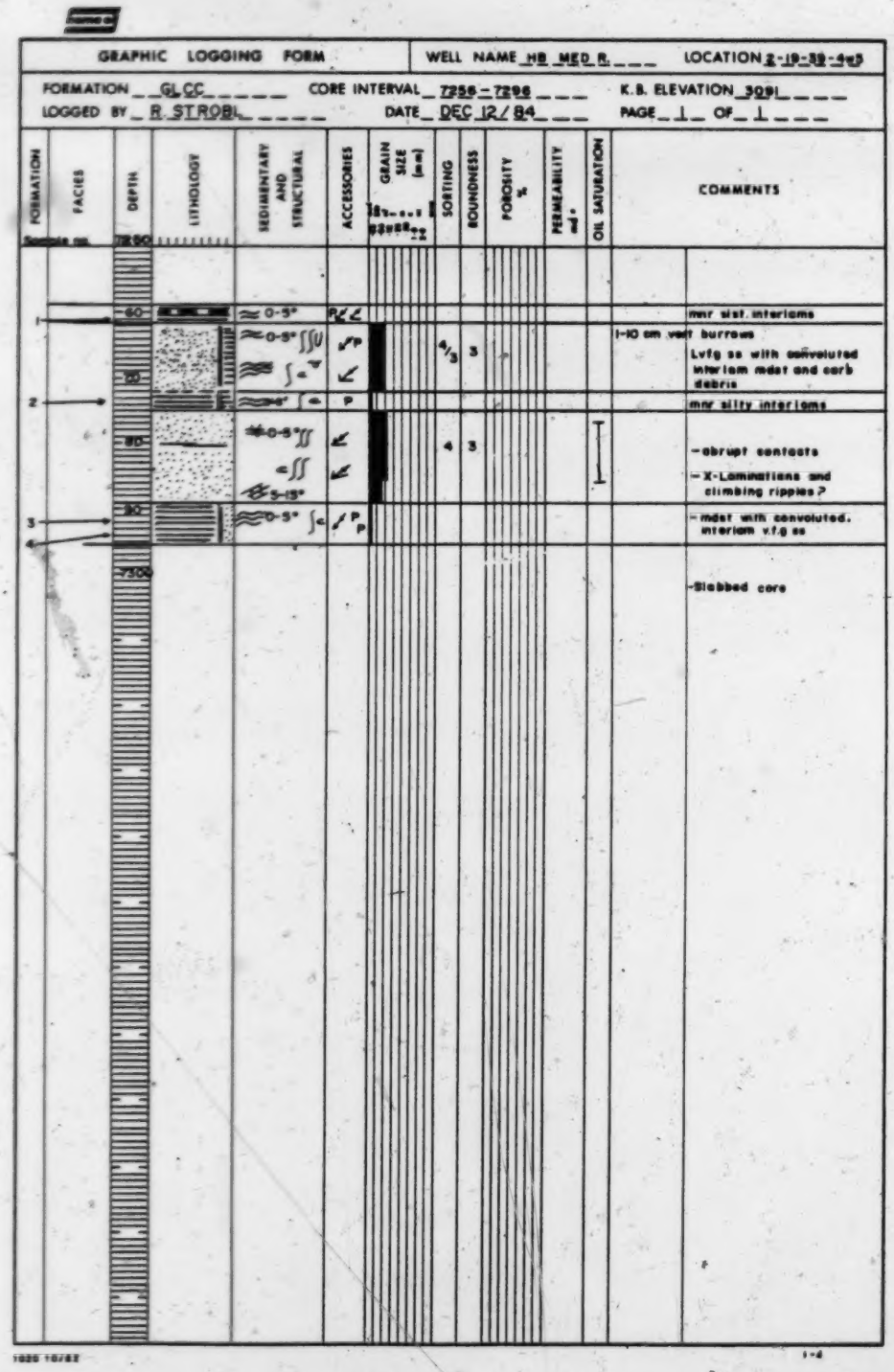
1020 10/82

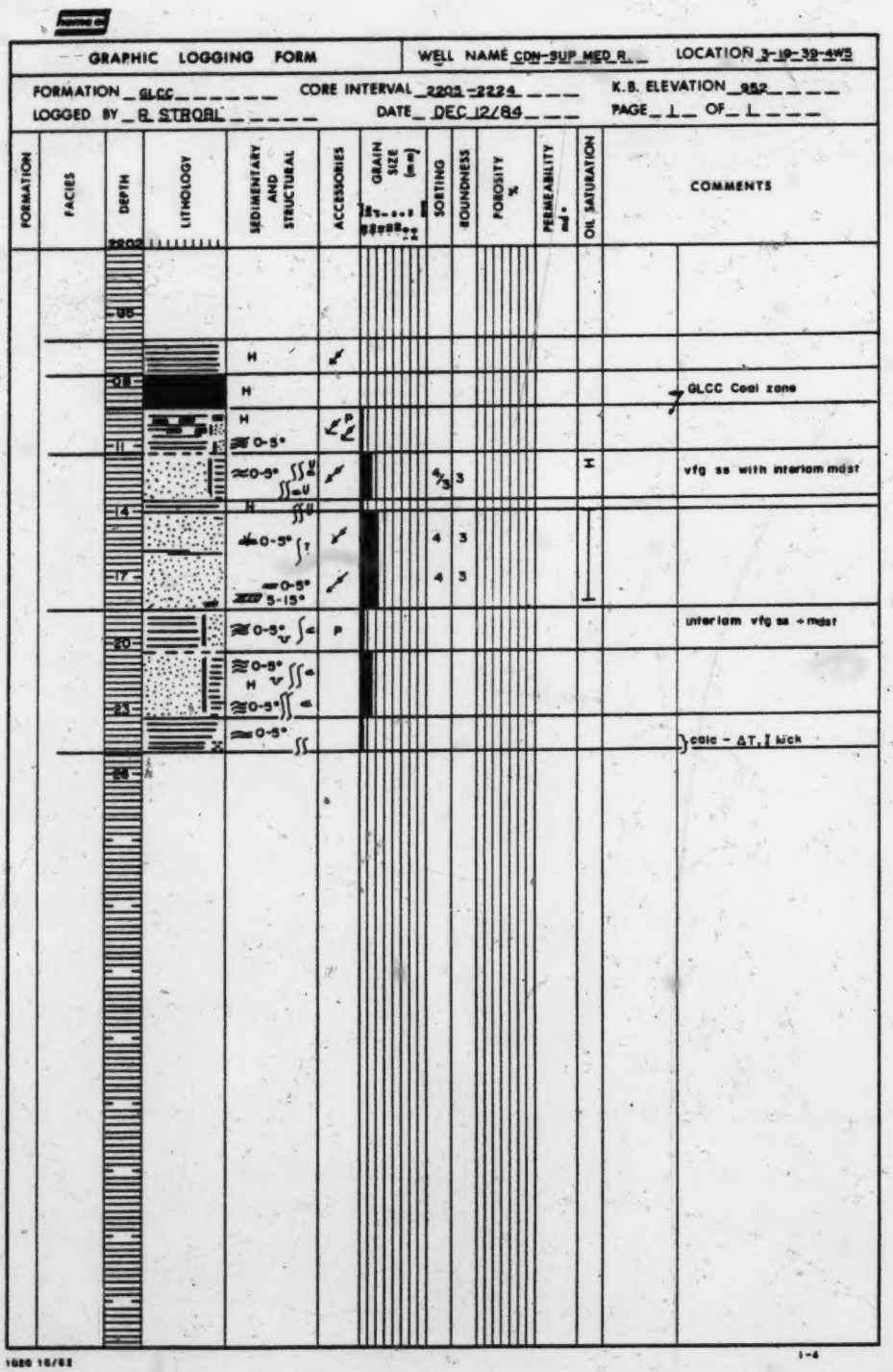

GRAPHIC LOGGING FORM
WELL NAME HB GLAUC A UNIT 1 MED-R
LOCATION 2-18-32-4W5
FORMATION GLCC
CORE INTERVAL 7358 - 7398
K.B. ELEVATION 3111
LOGGED BY R STROBL
DATE DEC 11/84
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md
OIL SATURATION
COMMENTS
7340
7400
GLCC coal zone overlies
sat in 10 cm zones
vfg ss with mdst lams
-alt interbed unsat L vfg ss with lam + massive vfg ss (sat)
- zones 10-30 cm.
- vertical burrow 10 cm long
interlam mdst + vfg ss.
also one large ss frag
1030 10/82
1-4

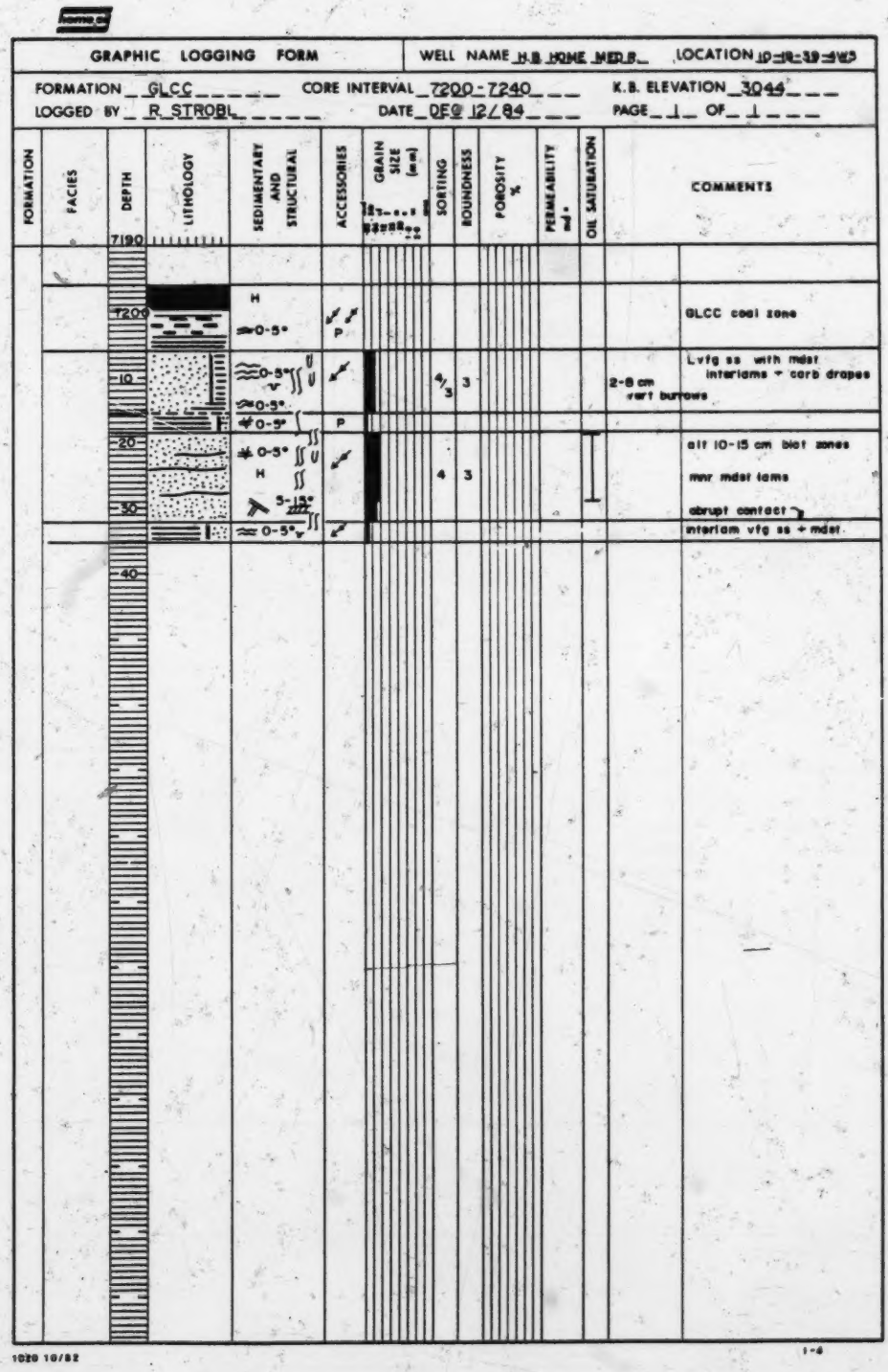

GRAPHIC LOGGING FORM
WELL NAME MURPHY TOTAL
LOCATION 4-18-39-4W5
FORMATION GLCC
CORE INTERVAL 7340-7400
K.B. ELEVATION 3128
LOGGED BY R STROBL
DATE DEC 11/84
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md.
OIL SATURATION
COMMENTS
7320
(between MRC and GLCC coal)
30
0-5°
0-5°
mdst with convol vfg ss interlams
40
H
MED R. COAL
50
60
0-5°
interlam mdst + vfg ss
70
0-15°
0-15°
4/3
3
abnt pore-filling clays
80
0-15°
0-5°
90
H
GLCC coal zone
-rubbled
7400
1020 10/82

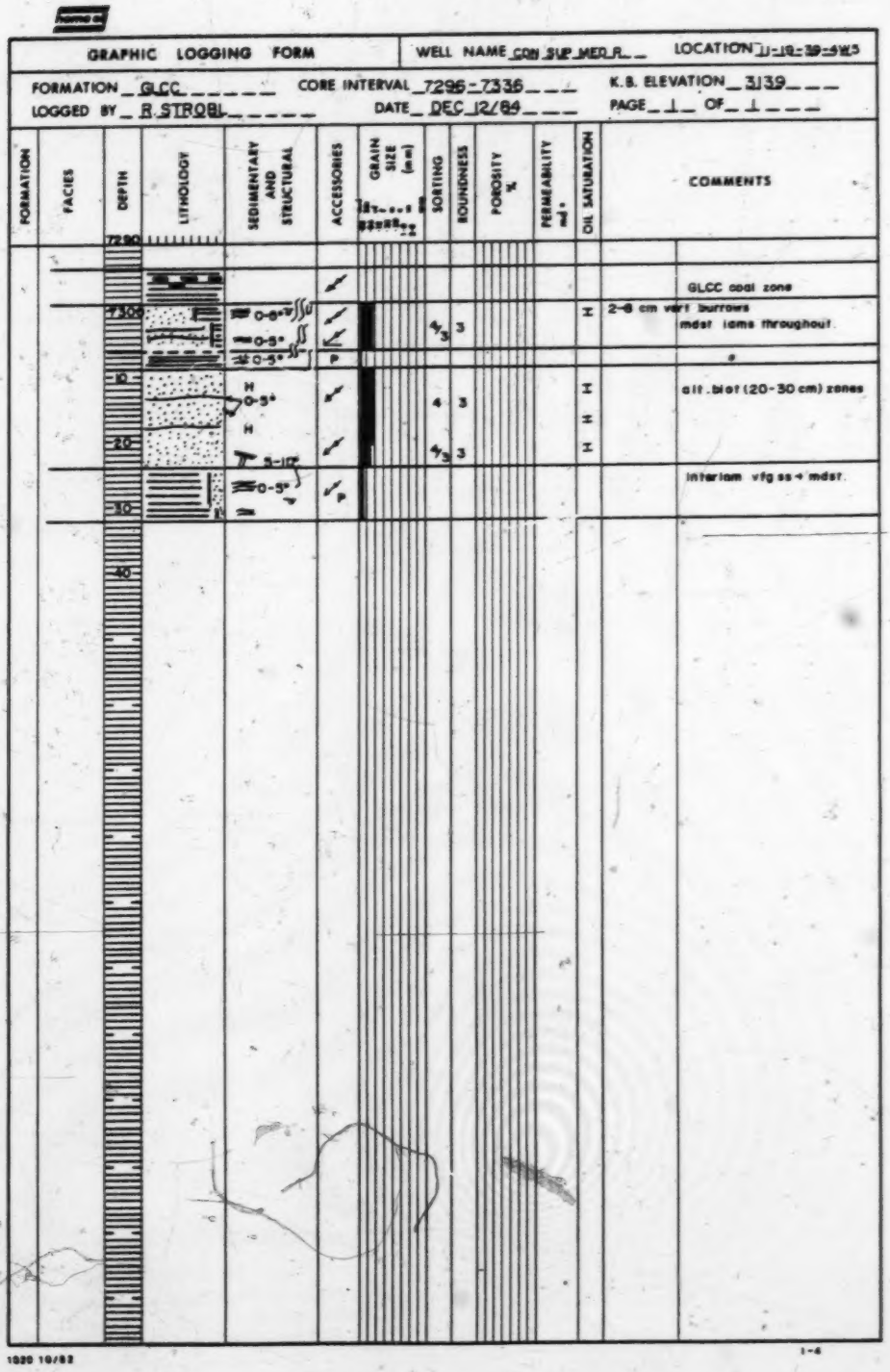

GRAPHIC LOGGING FORM
WELL NAME HR MED B
LOCATION 10-18-39-9W5
FORMATION GLCC
CORE INTERVAL 7318-7358
K.B. ELEVATION 3106
LOGGED BY R. STROBL
DATE DEC 12/84
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
7300
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md
OIL SATURATION
COMMENTS
10
20
30
40
50
60
0-5°
0-5°
0-10°
H
0-5°
H
5-15°
0-5°
0-5°
4
3
4
3
GLCC coal zone overlies
mvr vfg ss interlams
vfg ss with mdst lams (3-4 cm vert burrows)
biot associated with mdst lams
interlam vfg ss, mdst + mvr slst.

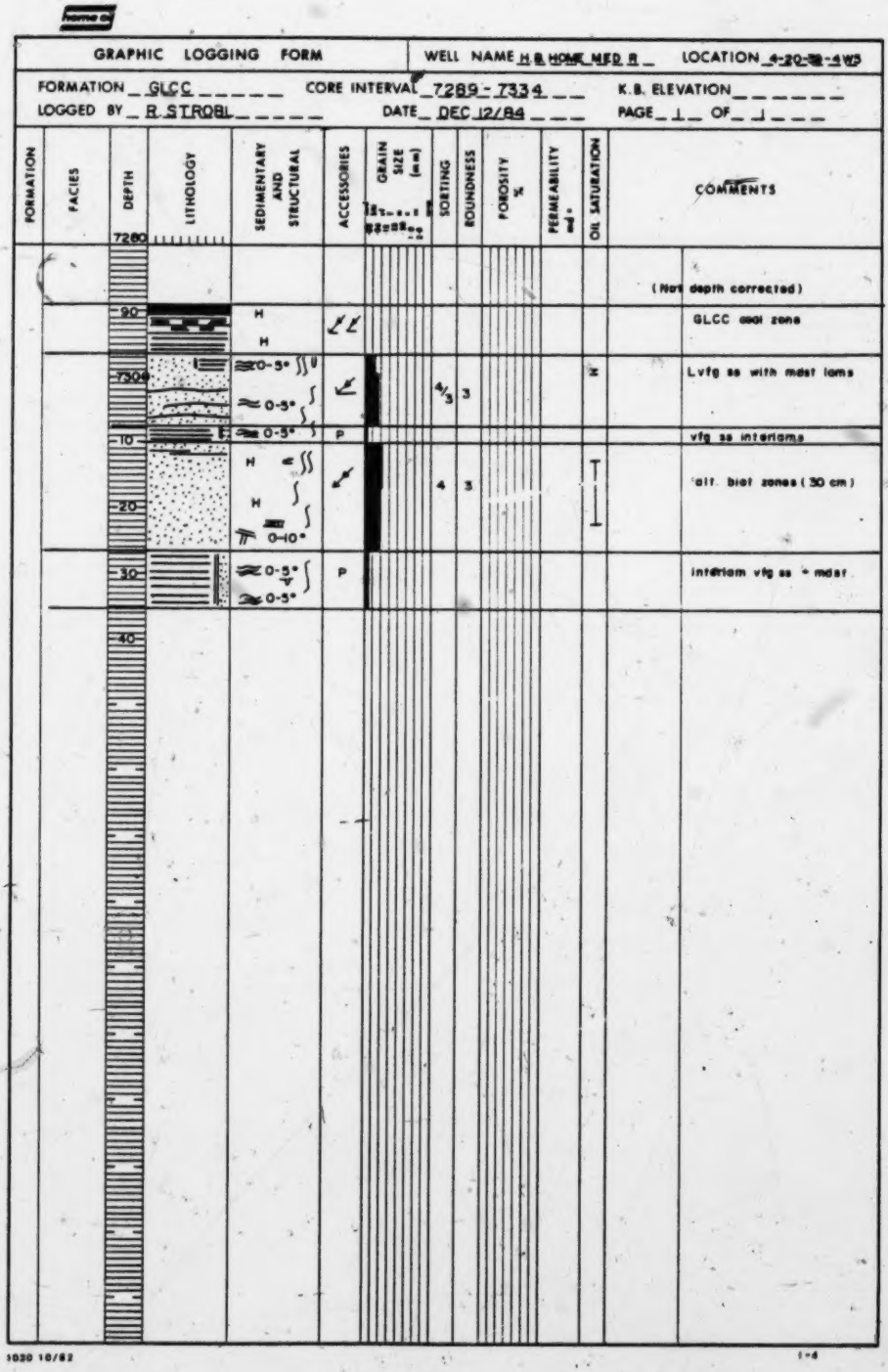
1-4


GRAPHIC LOGGING FORM
WELL NAME HB MED R.
LOCATION 2-19-39-4W5
FORMATION GLCC
CORE INTERVAL 7256-7298
K.B. ELEVATION 3091
LOGGED BY R. STROBL
DATE DEC 12/84
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md
OIL SATURATION
COMMENTS
7250
7300
mnr slst. interlams
1-10 cm vert burrows
Lvfg ss with convoluted interlam mdst and carb debris
mnr silty interlams
-abrupt contacts
-X-Laminations and climbing ripples?
-mdst with convoluted interlam v.f.g ss
-Slabbed core


GRAPHIC LOGGING FORM
WELL NAME CON-SUP MED R.
LOCATION 3-19-39-4W5
FORMATION GLCC
CORE INTERVAL 2203-2224
K.B. ELEVATION 952
LOGGED BY R. STROBL
DATE DEC 12/86
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md
OIL SATURATION
COMMENTS
2202
GLCC Coal zone
vfg ss with interlam mdst
interlam vfg ss + mdst
calc - AT, I kick

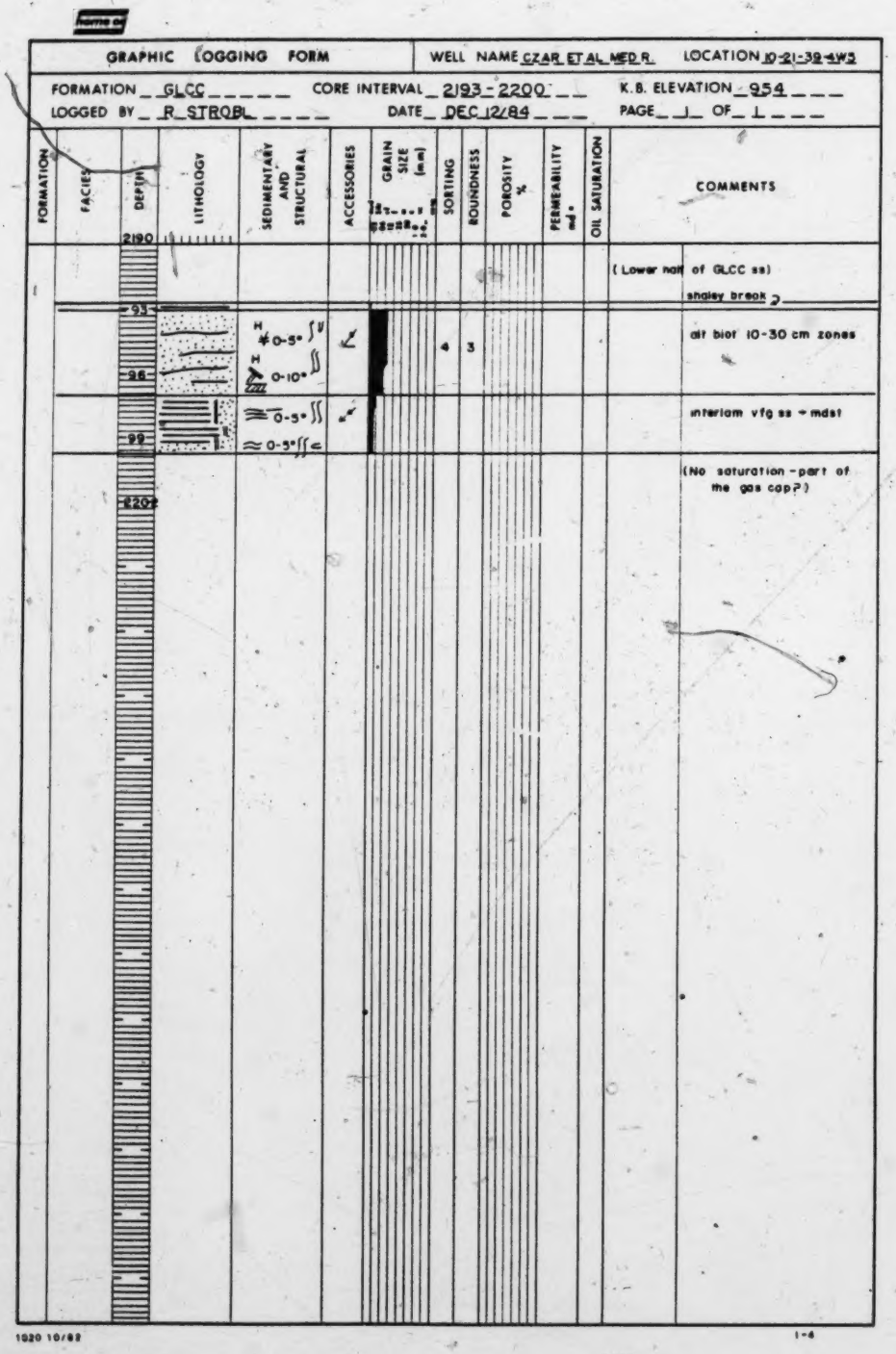

GRAPHIC LOGGING FORM
WELL NAME H.B. HOME MED.B.
LOCATION 10-18-39-5W5
FORMATION GLCC
CORE INTERVAL 7200-7240
K.B. ELEVATION 3044
LOGGED BY R STROBL
DATE DEC 12/84
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md.
OIL SATURATION
COMMENTS
7190
7200
10
20
30
40
H
0-5°
P
4/3
3
2-8 cm vert burrows
Lvfg ss with mdst interlams + carb drapes
0-5°
0-5°
0-5°
P
0-5°
H
5-15°
4
3
slt 10-15 cm biot zones
mnr mdst lams
abrupt contact
0-5°
interlam vfg ss + mdst
1020 10/82
1-6

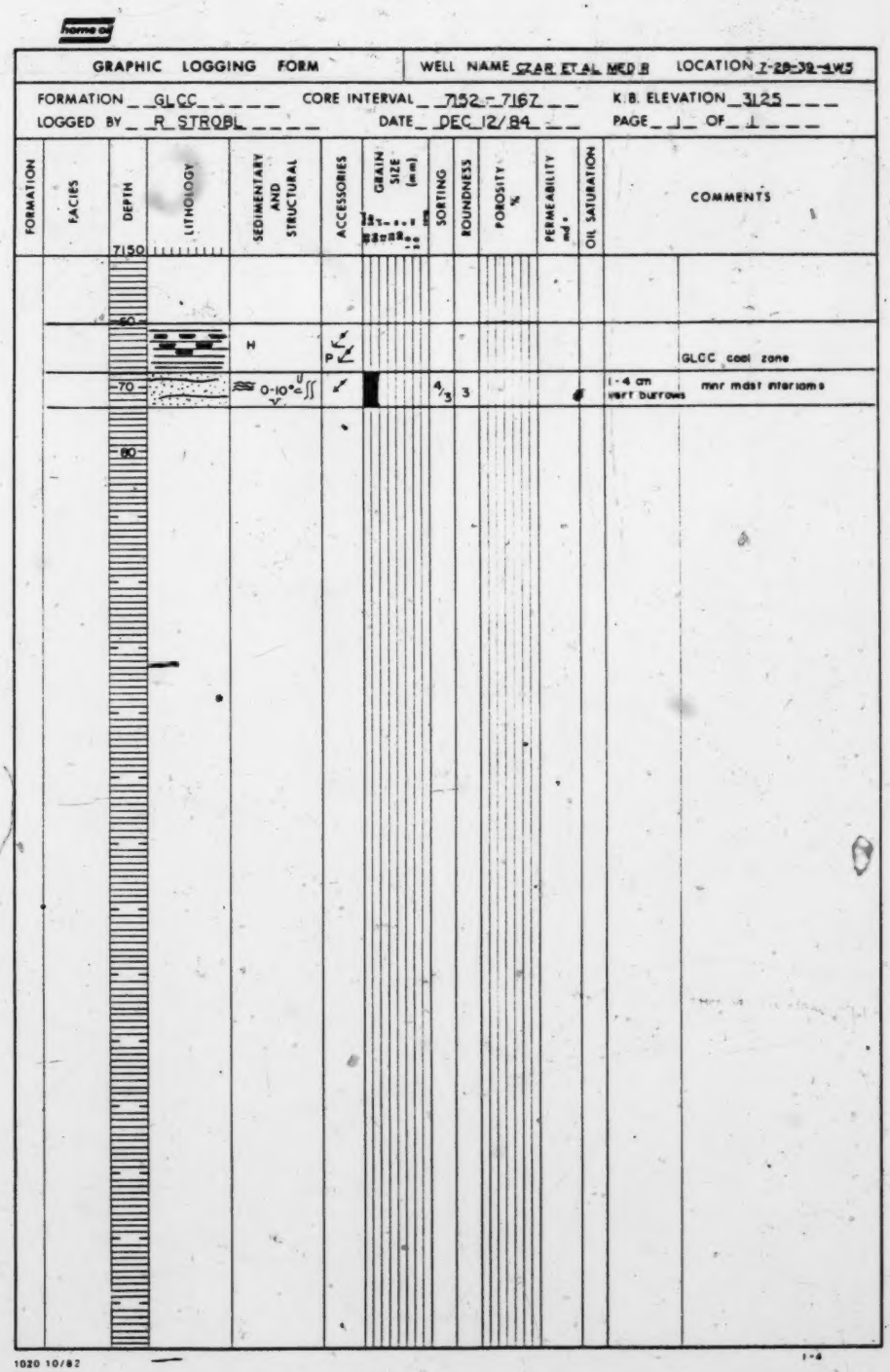

GRAPHIC LOGGING FORM
WELL NAME CDN SUP MED R.
LOCATION
FORMATION GLCC
CORE INTERVAL 7296-7336
K.B. ELEVATION 3139
LOGGED BY R STROBL
DATE DEC 12/84
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md
OIL SATURATION
COMMENTS
7290
7300
10
20
30
40
0-5°
5-10°
H
P
GLCC coal zone
2-6 cm vert burrows mdst lams throughout
alt. bio (20-30 cm) zones
interlam vfg ss + mdst.


GRAPHIC LOGGING FORM
WELL NAME H.B. HOME MED. R.
LOCATION 4-20-38-4W5
FORMATION GLCC
CORE INTERVAL 7289 - 7334
K.B. ELEVATION
LOGGED BY R. STROBL
DATE DEC 12/84
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md
OIL SATURATION
COMMENTS
7280
90
7300
10
20
30
40
(Not depth corrected)
GLCC coal zone
Lvfg ss with mdst lams
vfg ss interlams
oil. biot zones (30 cm)
interlam vfg ss + mdst
0-5°
0-10°
H
P
4/3
3
4
3

1030 10/82

1-4


GRAPHIC LOGGING FORM
WELL NAME CZAR ET AL MED R. LOCATION 10-21-38-4W3
FORMATION GLCC
CORE INTERVAL 2193-2200
K.B. ELEVATION 954
LOGGED BY R STROBL
DATE DEC 12/84
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md.
OIL SATURATION
COMMENTS
2190
93
96
99
2202
0-5°
0-10°
0-5°
0-5°
4
3
(Lower part of GLCC ss)
shaley break
slt biot 10-30 cm zones
interlam vfg ss → mdst
(No saturation - part of the gas cap?)
1020 10/82
1-4



GRAPHIC LOGGING FORM

WELL NAME CZAR ET AL MED B LOCATION 7-29-32-4W5

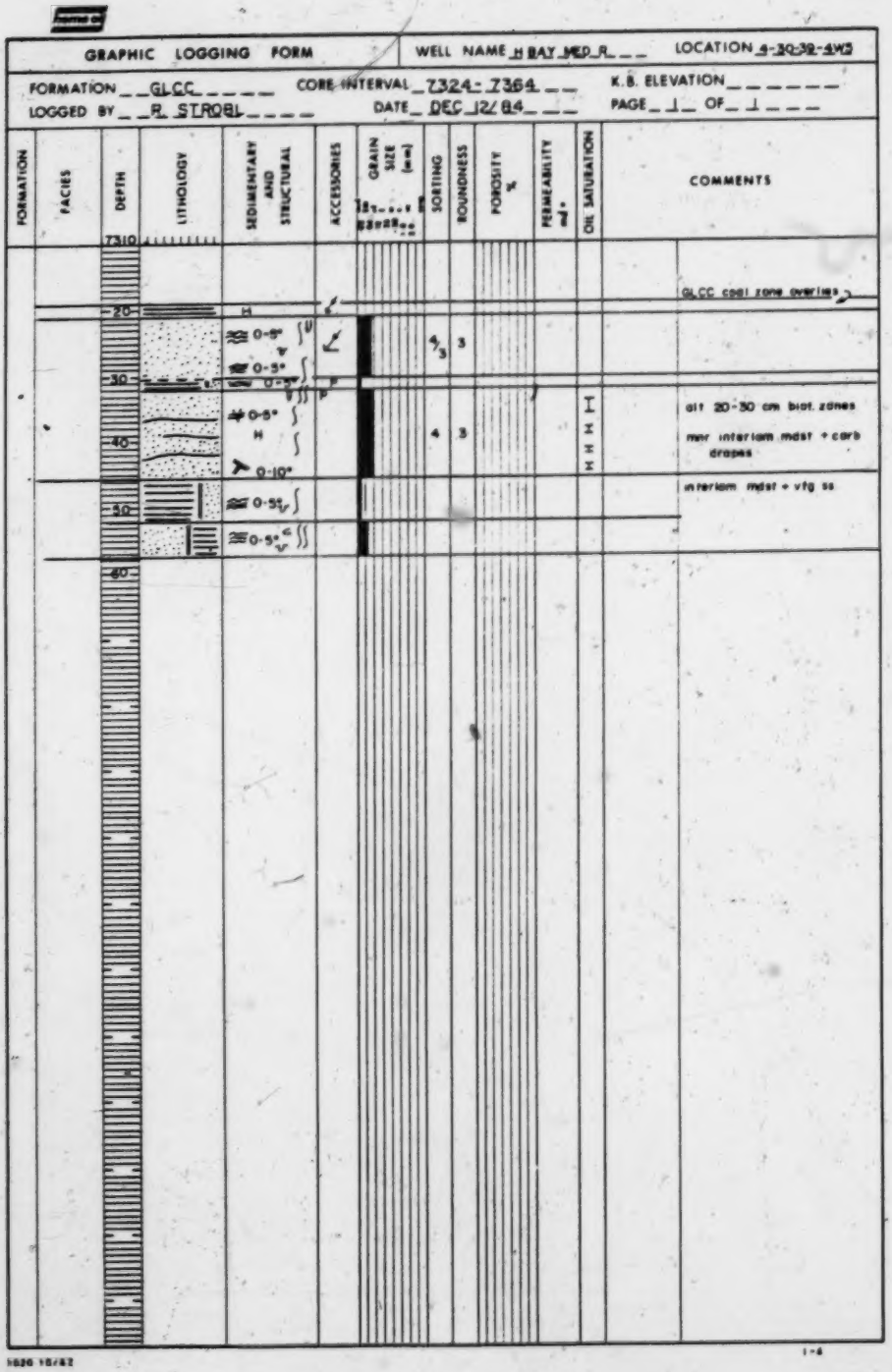
FORMATION GLCC CORE INTERVAL 7152 - 7167 K.B. ELEVATION 3125

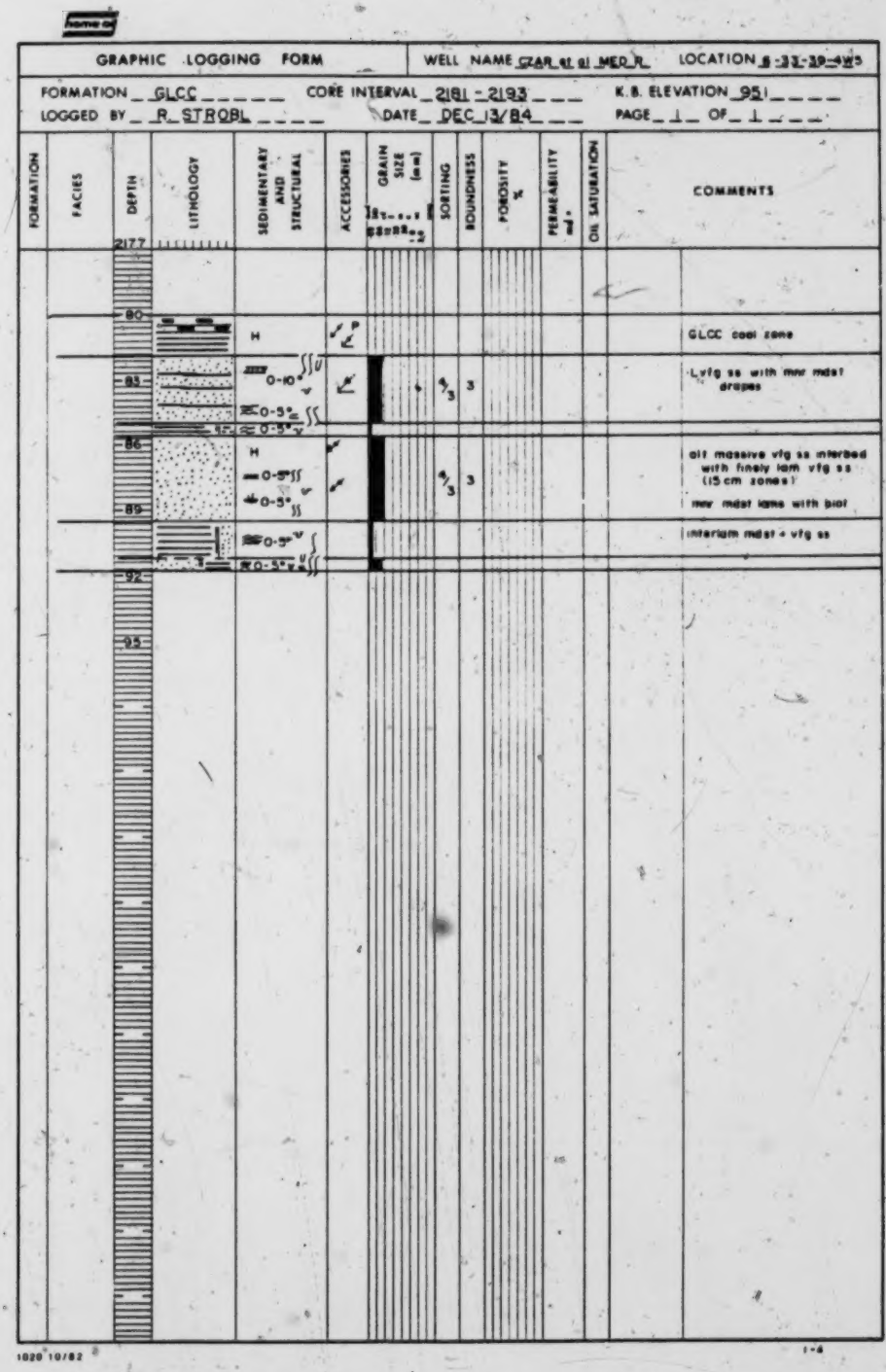
LOGGED BY R STROBL DATE DEC 12/84 PAGE 1 OF 1

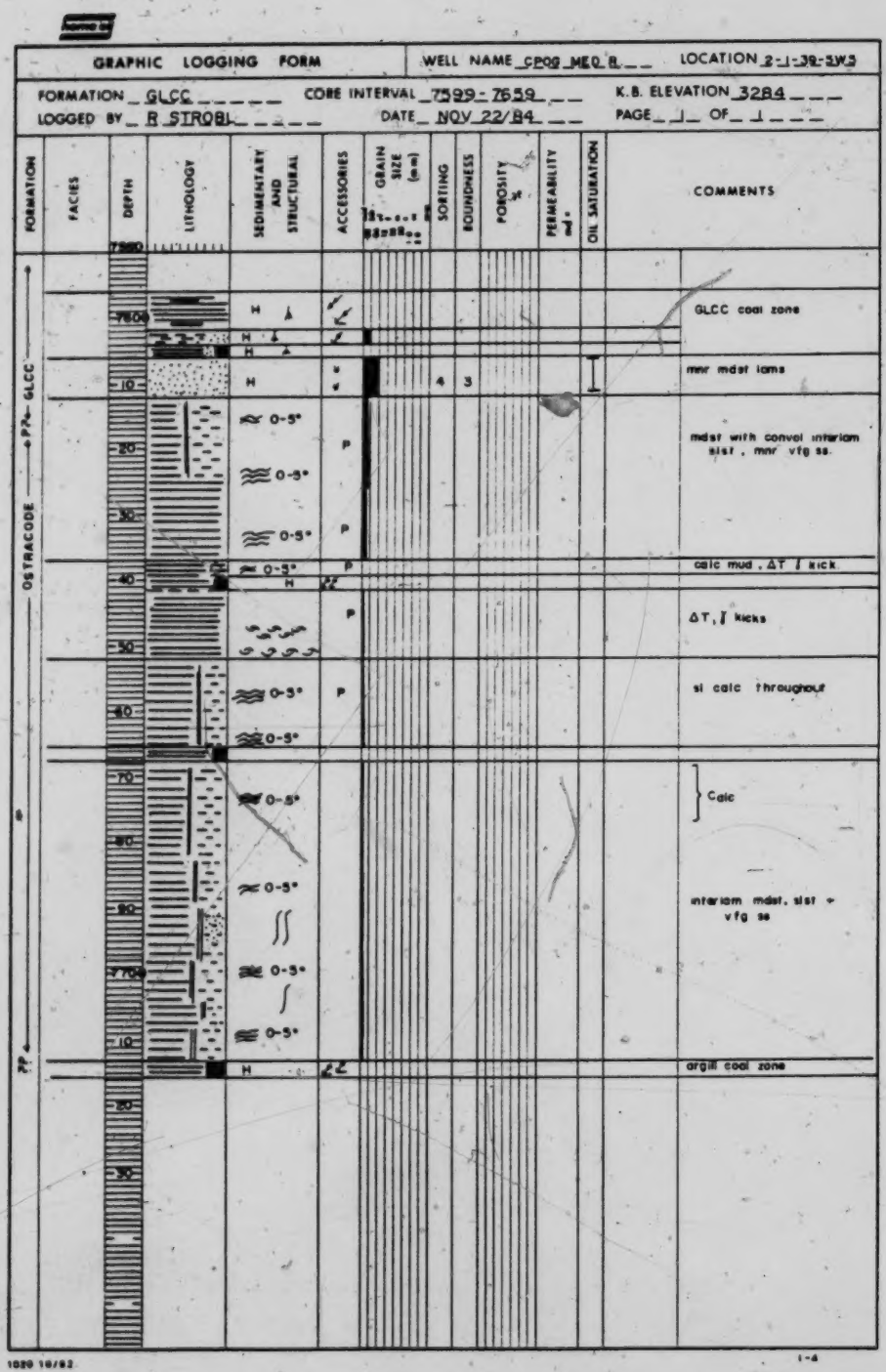
FORMATION	FACIES	DEPTH	LITHOLOGY	SEDIMENTARY AND STRUCTURAL	ACCESSORIES	GRAIN SIZE (mm)	SORTING	ROUNDNESS	POROSITY %	PERMEABILITY md.	OIL SATURATION	COMMENTS
		7150										
		60		H	P							GLCC coal zone
		70		0-10°			4/3	3				1-4 cm vert burrows mar mdst interlams
		80										

1020 10/82

1-4


GRAPHIC LOGGING FORM
WELL NAME H BAY MED R
LOCATION 4-30-38-4W5
FORMATION GLCC
CORE INTERVAL 7324-7364
K.B. ELEVATION
LOGGED BY R STROBL
DATE DEC 12/84
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY mD
OIL SATURATION
COMMENTS
7310
20
30
40
50
60
0-5°
0-5°
0-5°
0-5°
0-10°
0-5°
0-5°
GLCC coal zone overlies
slt 20-30 cm biot. zones
mnr interlam mdst + carb drapes
interlam mdst + vfg ss


GRAPHIC LOGGING FORM
WELL NAME CZAR et al MEDL
LOCATION 8-33-39-4W5
FORMATION GLCC
CORE INTERVAL 2181 - 2193
K.B. ELEVATION 951
LOGGED BY R. STROBL
DATE DEC 13/84
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md
OIL SATURATION
COMMENTS
2177
80
83
86
89
92
95
H
0-10°
0-5°
GLCC coal zone
Lvfg ss with mm mdst drapes
clt massive vfg ss interbed with finely lam vfg ss (15 cm zones)
mm mdst lams with biot
interlam mdst + vfg ss
1020 10/82
1-4


GRAPHIC LOGGING FORM
WELL NAME CPOG MEQ 8
LOCATION 2-1-38-5W3
FORMATION GLCC
CORE INTERVAL 7589-7659
K.B. ELEVATION 3284
LOGGED BY R STROBL
DATE NOV 22/84
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (m)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md
OIL SATURATION
COMMENTS
GLCC coal zone
mnr mdst lams
mdst with convol interlam sist , mnr vfg ss.
calc mud , ΔT ∫ kick
ΔT, ∫ kicks
sl calc throughout
Calc
interlam mdst, sist + vfg ss
argill coal zone
OSTRACODE
PP
PP GLCC
7600
7700
0-5°
H
P

1020 10/82

1-4

Schlumberger

GRAPHIC LOGGING FORM

WELL NAME PCP MED R LOCATION 9-1-39-5W5

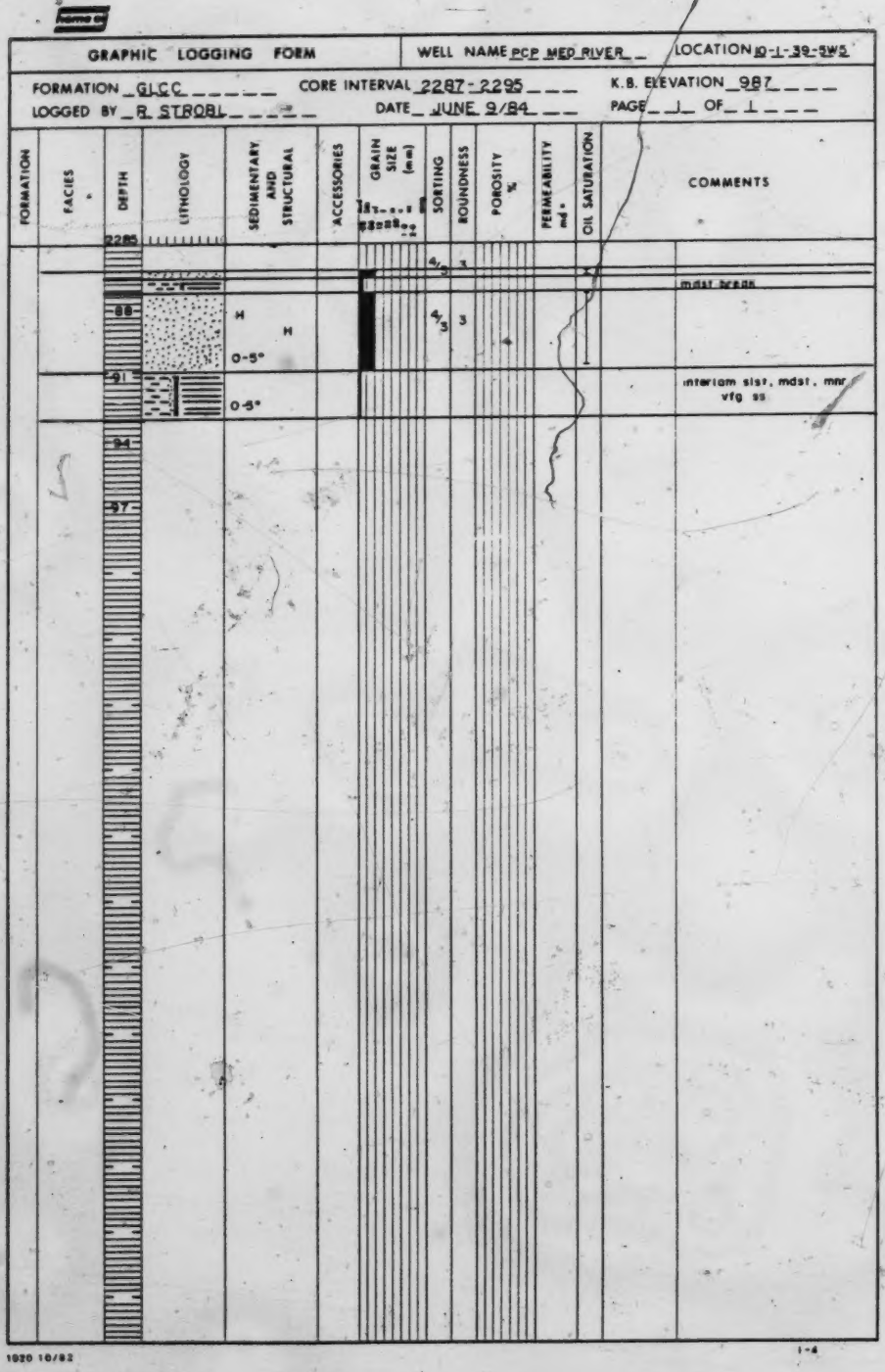
FORMATION GLCC CORE INTERVAL 2280-2296.6 K.B. ELEVATION 978

LOGGED BY R STROBL DATE NOV 21/84 PAGE 1 OF 1

FORMATION	FACIES	DEPTH	LITHOLOGY	SEDIMENTARY AND STRUCTURAL	ACCESSORIES	GRAIN SIZE (mm)	SORTING	ROUNDNESS	POROSITY %	PERMEABILITY md.	OIL SATURATION	COMMENTS
		2577										
		2580										
				H								GLCC coal zone
		83		0-5°			4	3				some mud drapes
		86		0-5°								
				0-10°			4	3				possible climbing ripples?
		89										interlam sltst + mdst with mm ss pulses
		92		0-5°								
				0-5°								
		95		H								calc. at base - ΔT_t kick
		98										

1020 10/82

1-4


GRAPHIC LOGGING FORM
WELL NAME PCP MED RIVER
LOCATION 10-1-39-9W5
FORMATION GLCC
CORE INTERVAL 2287-2295
K.B. ELEVATION 987
LOGGED BY R. STROBL
DATE JUNE 9/84
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md
OIL SATURATION
COMMENTS
2285
88
91
94
97
H
H
0-5°
0-5°
4/3
3
4/3
3
4
mdst w/ss
interlam sist, mdst, mnr vfg ss
1920 10/82
1-4

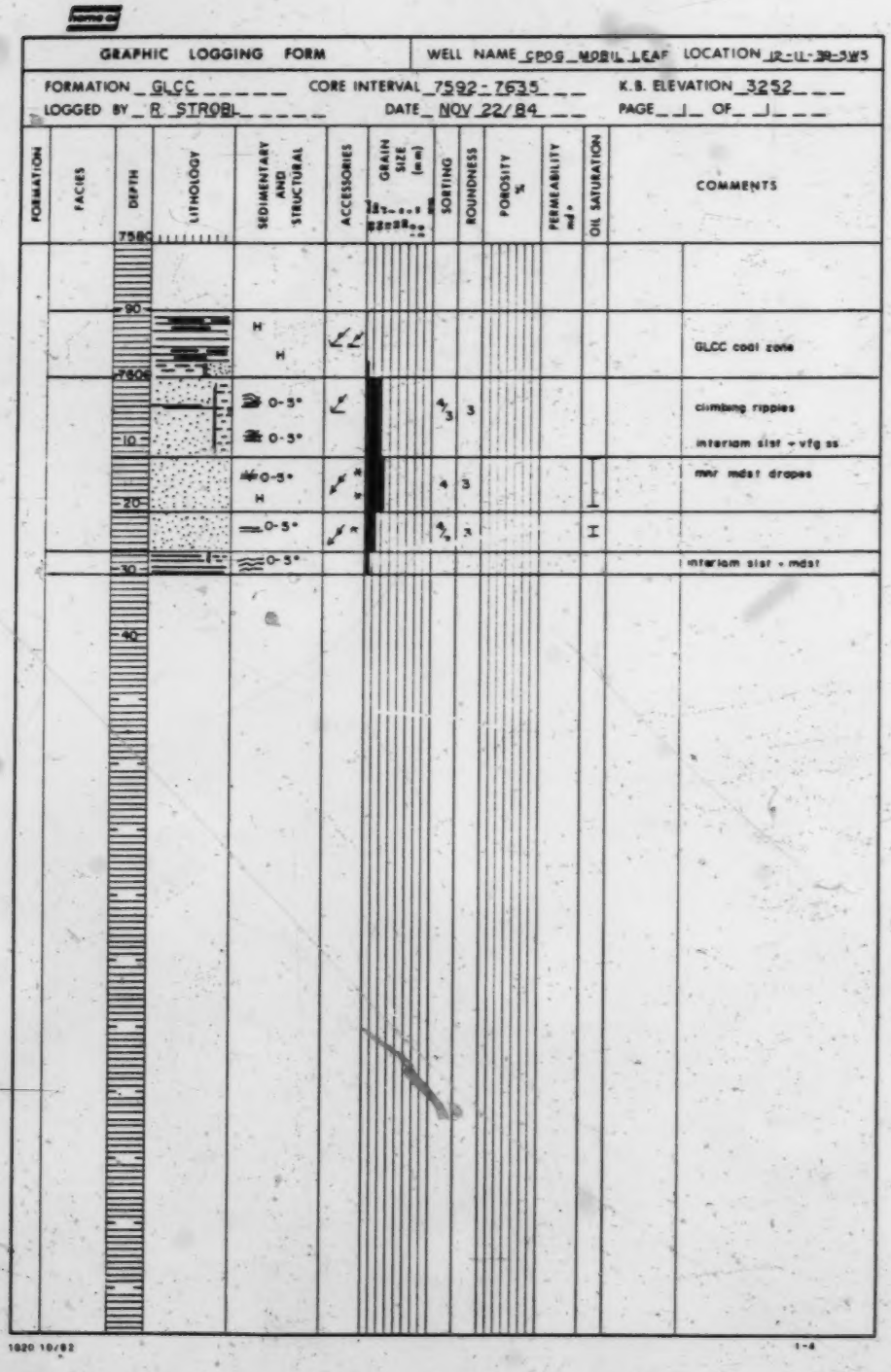
GRAPHIC LOGGING FORM — WELL NAME MOBIL MEQ RIVER — LOCATION 15-2-38-24W5

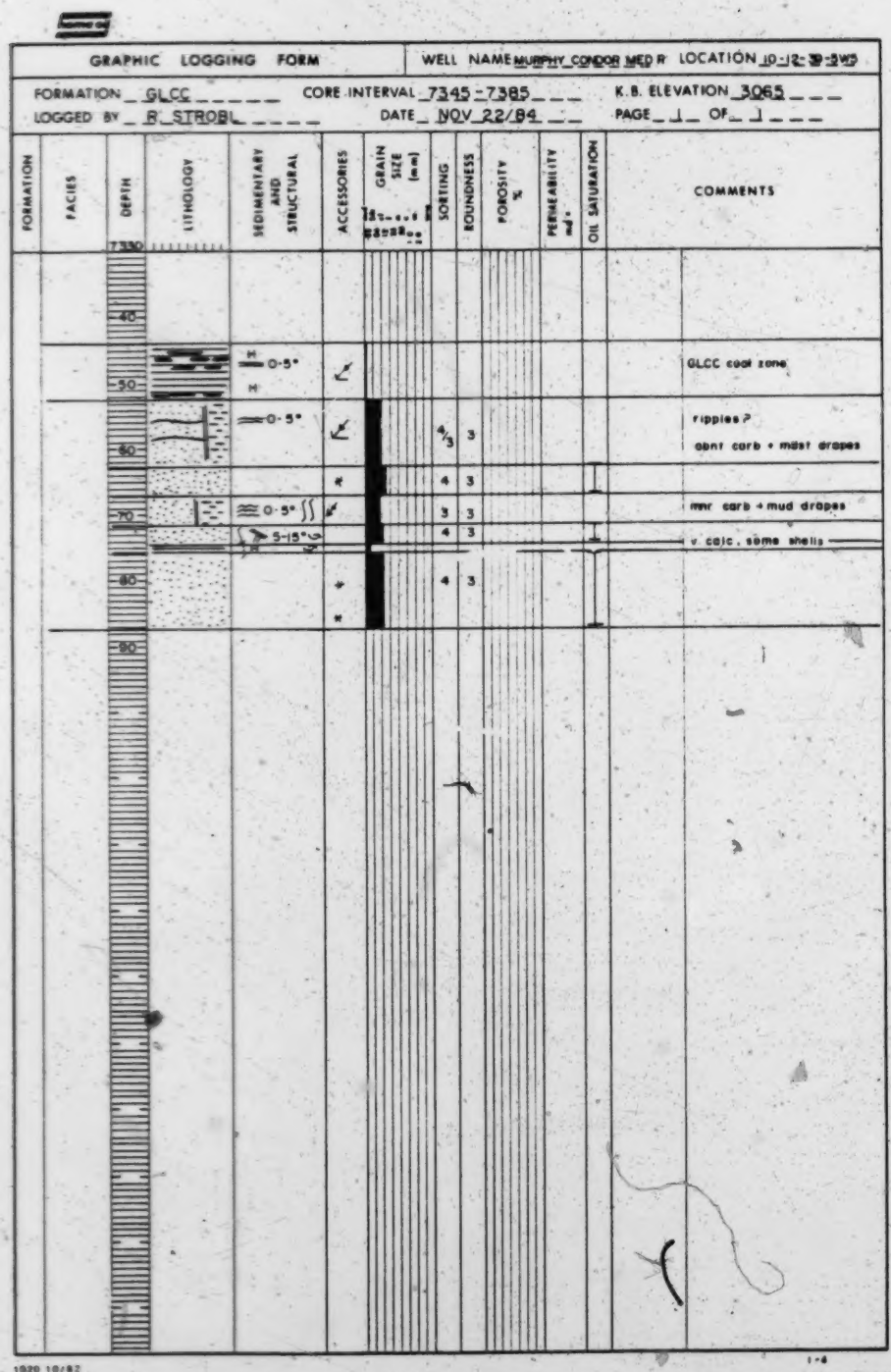
FORMATION GLCC — CORE INTERVAL 2319.3 - 2337.8 — K.B. ELEVATION 997

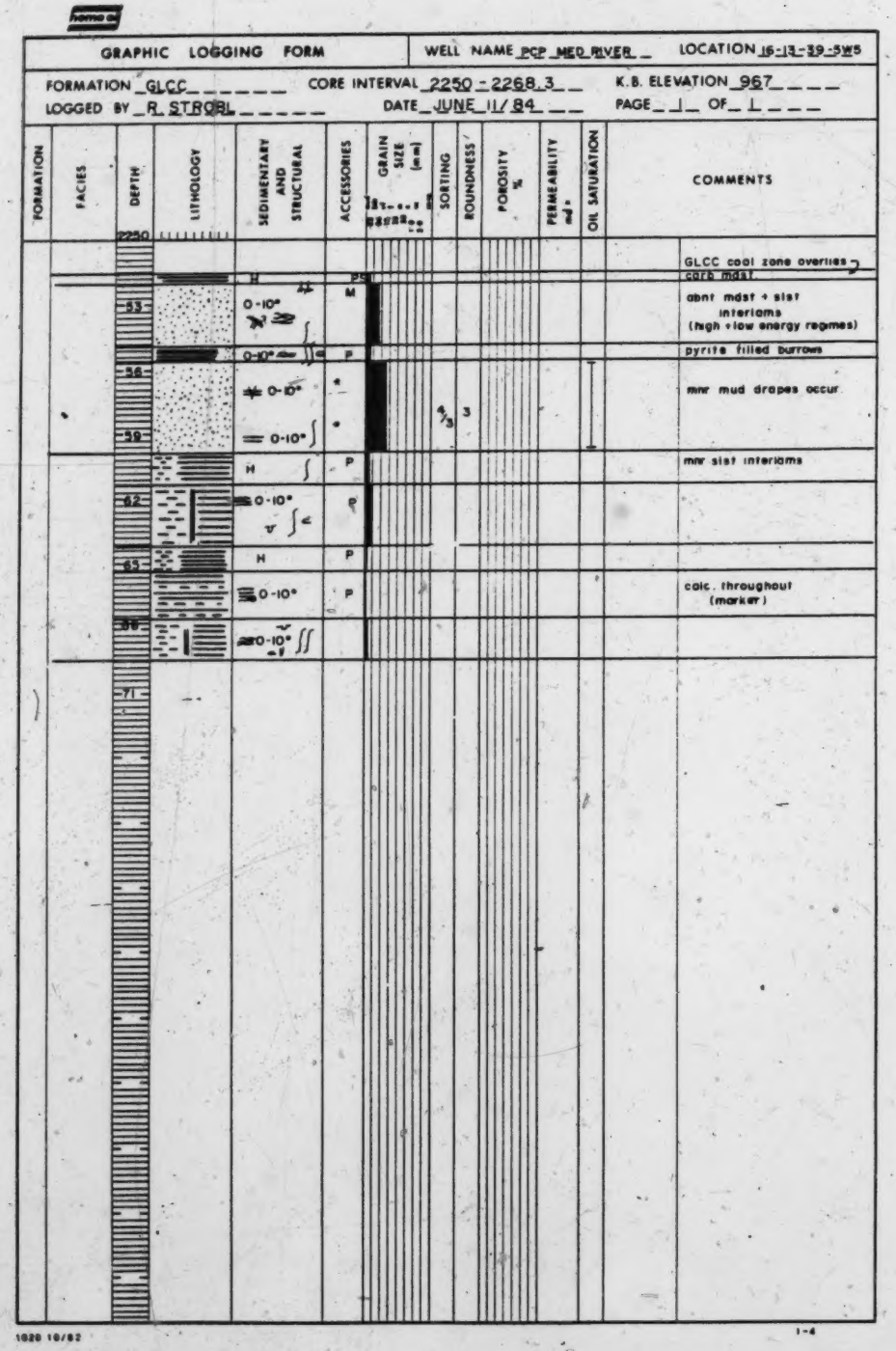
LOGGED BY R. STROBL — DATE JUNE 11/84 — PAGE 1 OF 1

DEPTH	LITHOLOGY	SEDIMENTARY AND STRUCTURAL	ACCESSORIES	SORTING	ROUNDNESS	COMMENTS
2317						
						GLCC coal zone overlies
20		0-5°		4/3	3	Oil stained in middle intervals
23		0-10°				Mnr clay drapes throughout
		0-5°		4/3	3	
26		0-10°	P			interlam slst + mdst
29		0-10°	P			
		H	P			silty mdst w pyrite bands
32		0-10°	P			Calc mdst with mnr slst interlams
		a	P			sl. calc
35		0-5°				calcareous
		0-10°				
38						

1020 10/82


GRAPHIC LOGGING FORM
WELL NAME CPOG MOBIL LEAF LOCATION 12-11-39-5W5
FORMATION GLCC
CORE INTERVAL 7592-7635
K.B. ELEVATION 3252
LOGGED BY R STROBL
DATE NOV 22/84
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md
OIL SATURATION
COMMENTS
7580
90
7600
10
20
30
40
H
0-5°
GLCC coal zone
climbing ripples
interlam slst - vfg ss
mm mdst drapes
interlam slst - mdst
1920 10/82
1-4


GRAPHIC LOGGING FORM
WELL NAME MURPHY CONDOR MED R LOCATION 10-12-38-2W5
FORMATION GLCC
CORE INTERVAL 7345-7385
K.B. ELEVATION 3065
LOGGED BY R STROBL
DATE NOV 22/84
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md
OIL SATURATION
COMMENTS
7330
40
50
60
70
80
90
0-5°
0-5°
0-5°
5-15°
GLCC coal zone
ripples?
abnt carb + mast drapes
mnr carb + mud drapes
v calc, some shells


GRAPHIC LOGGING FORM
WELL NAME PCP MED RIVER
LOCATION 16-13-39-5W5
FORMATION GLCC
CORE INTERVAL 2250 - 2268.3
K.B. ELEVATION 967
LOGGED BY R. STROBL
DATE JUNE 11/84
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md
OIL SATURATION
COMMENTS
2250
GLCC coal zone overlies
carb mdst
abnt mdst + slst interlams (high + low energy regmes)
pyrite filled burrows
mnr mud drapes occur
mnr slst interlams
calc. throughout (marker)
1020 10/82
1-4

GRAPHIC LOGGING FORM

WELL NAME CPOG LEAFLAND LOCATION 6-15-38-5W5

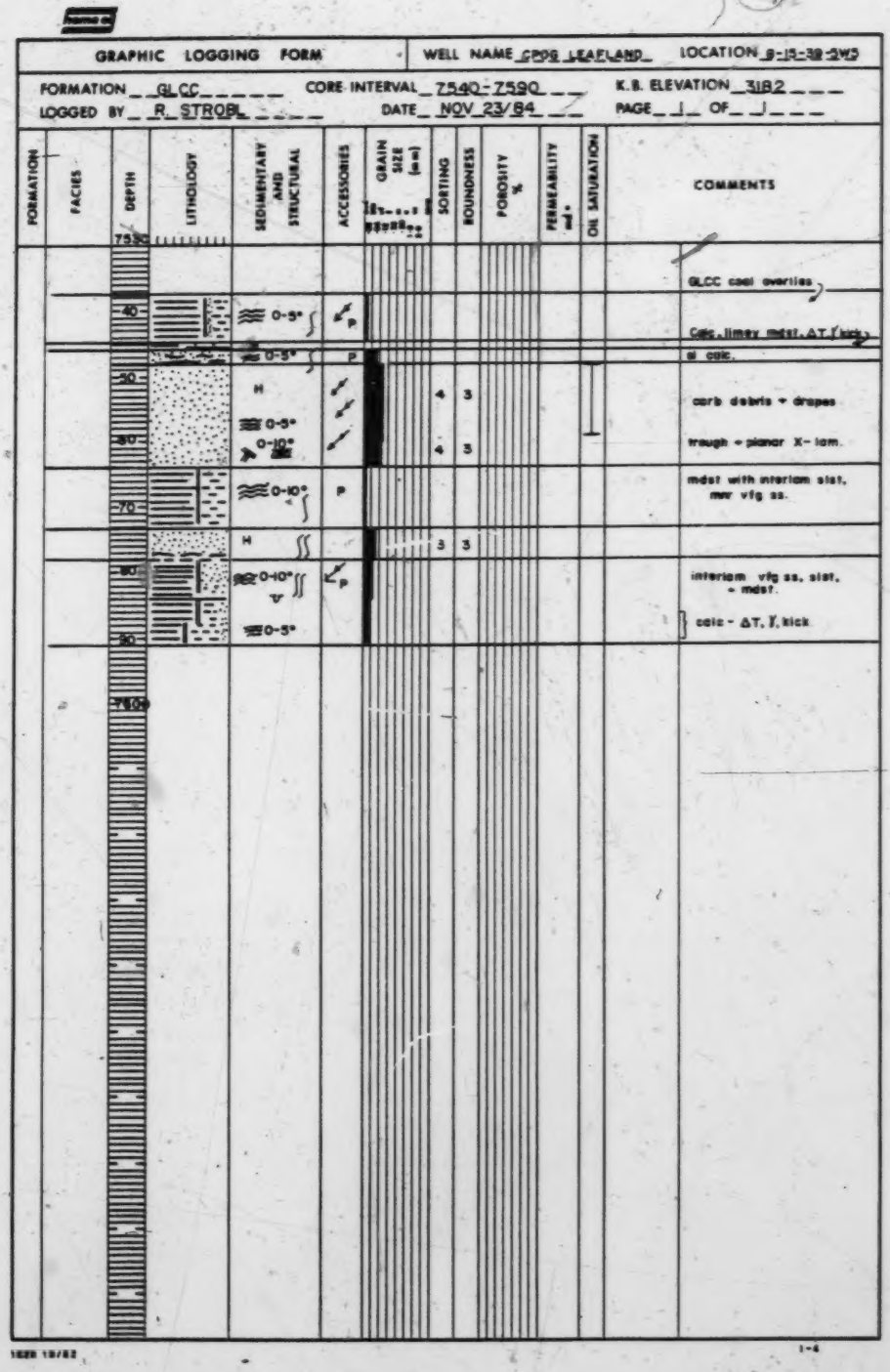
FORMATION GLCC CORE INTERVAL 7549 - 7585 K.B. ELEVATION 3177

LOGGED BY R. STROBL DATE JUNE 6/84 PAGE 1 OF 1

FORMATION	FACIES	DEPTH	LITHOLOGY	SEDIMENTARY AND STRUCTURAL	ACCESSORIES	GRAIN SIZE (mm)	SORTING	ROUNDNESS	POROSITY %	PERMEABILITY md	OIL SATURATION	COMMENTS
		7550										
		60		0-5°								dkgy clay + carb lams
				0-5°								
				0-5°								mud drapes
		70										
		80		0-5°	P							blot, interlam slst, mdst, mm vfg ss.
					P							
		90		0-10°								mdst interlams
		7600										

1020 10/82

1-4

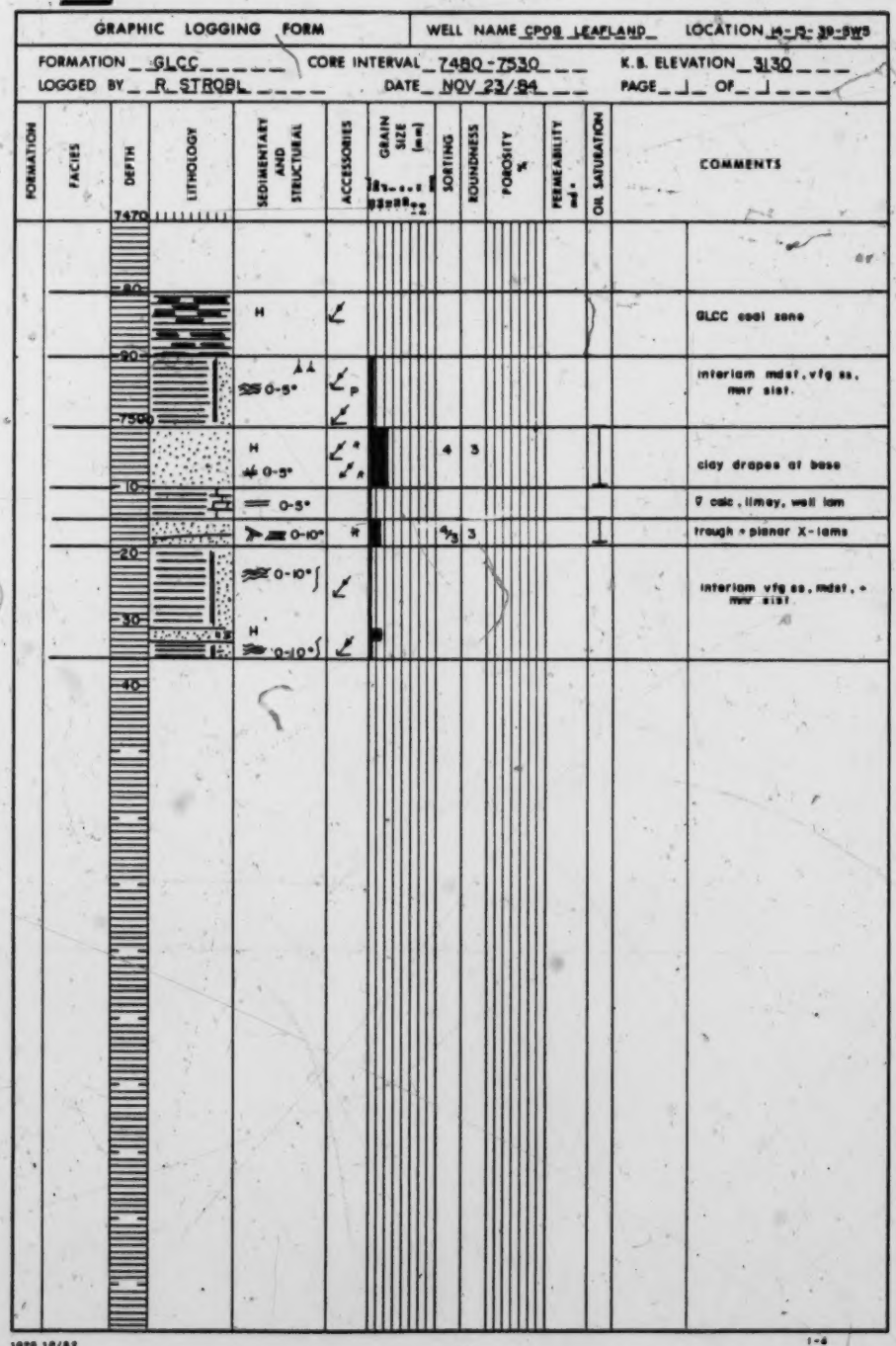

GRAPHIC LOGGING FORM
WELL NAME GPDS LEAFLAND
LOCATION 9-13-38-2W5
FORMATION GLCC
CORE INTERVAL 7540-7590
K.B. ELEVATION 3182
LOGGED BY R. STROBL
DATE NOV 23/84
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md
OIL SATURATION
COMMENTS
7530
40
0-5°
P
GLCC coal overlies
Calc. limey mdst. ΔT, γ kick
50
0-5°
P
sl calc.
H
4
3
carb debris + drapes
0-5°
60
0-10°
4
3
trough + planar X-lam.
70
0-10°
P
mdst with interlam slst, mav vfg ss.
H
3
3
80
0-10°
P
interlam vfg ss, slst, + mdst.
V
0-5°
calc - ΔT, γ kick
90
7600

GRAPHIC LOGGING FORM

WELL NAME CPOG LEAFLAND LOCATION 14-15-39-5W5

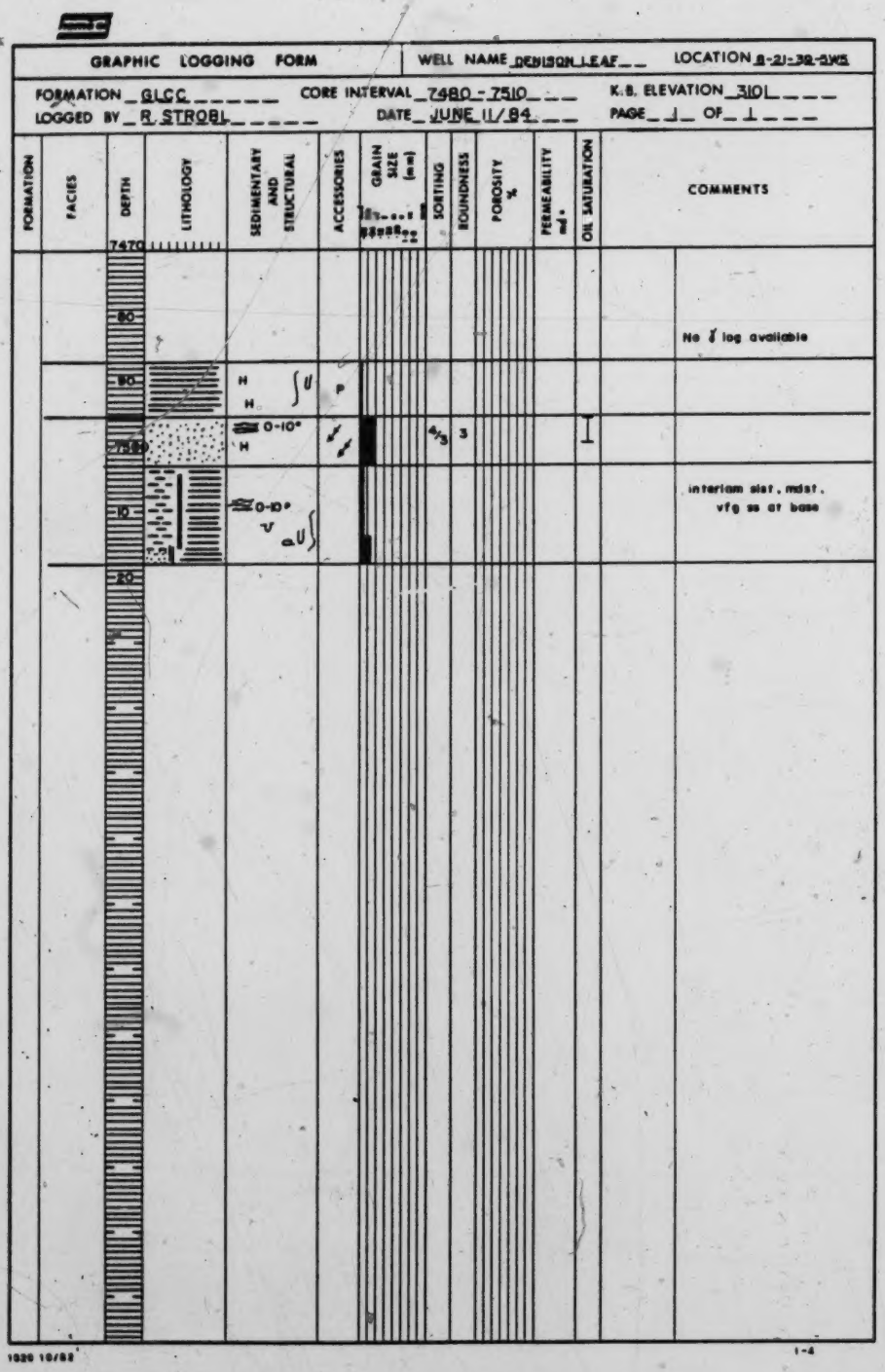
FORMATION GLCC CORE INTERVAL 7480-7530 K.B. ELEVATION 3130

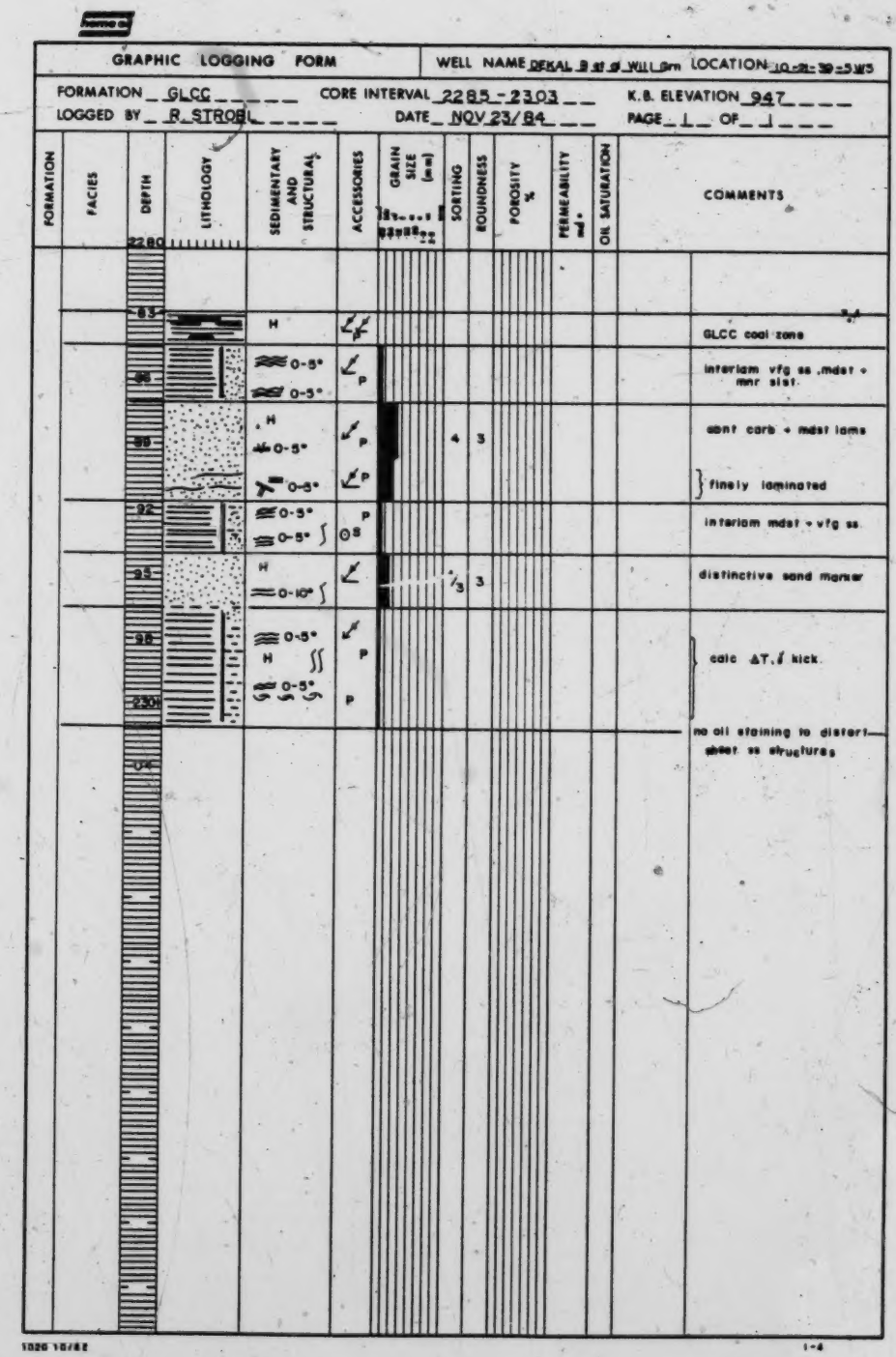
LOGGED BY R. STROBL DATE NOV 23/84 PAGE 1 OF 1

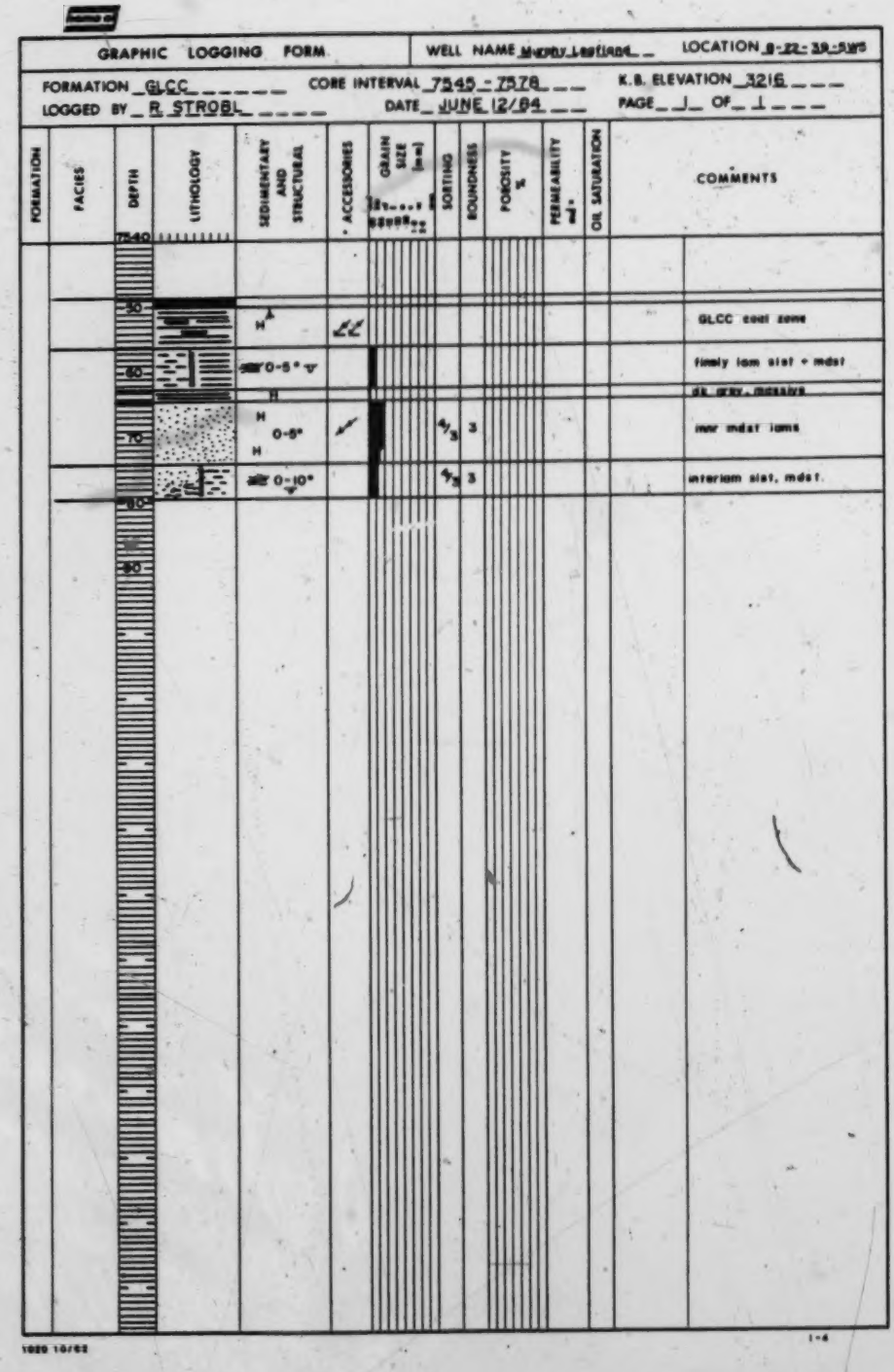


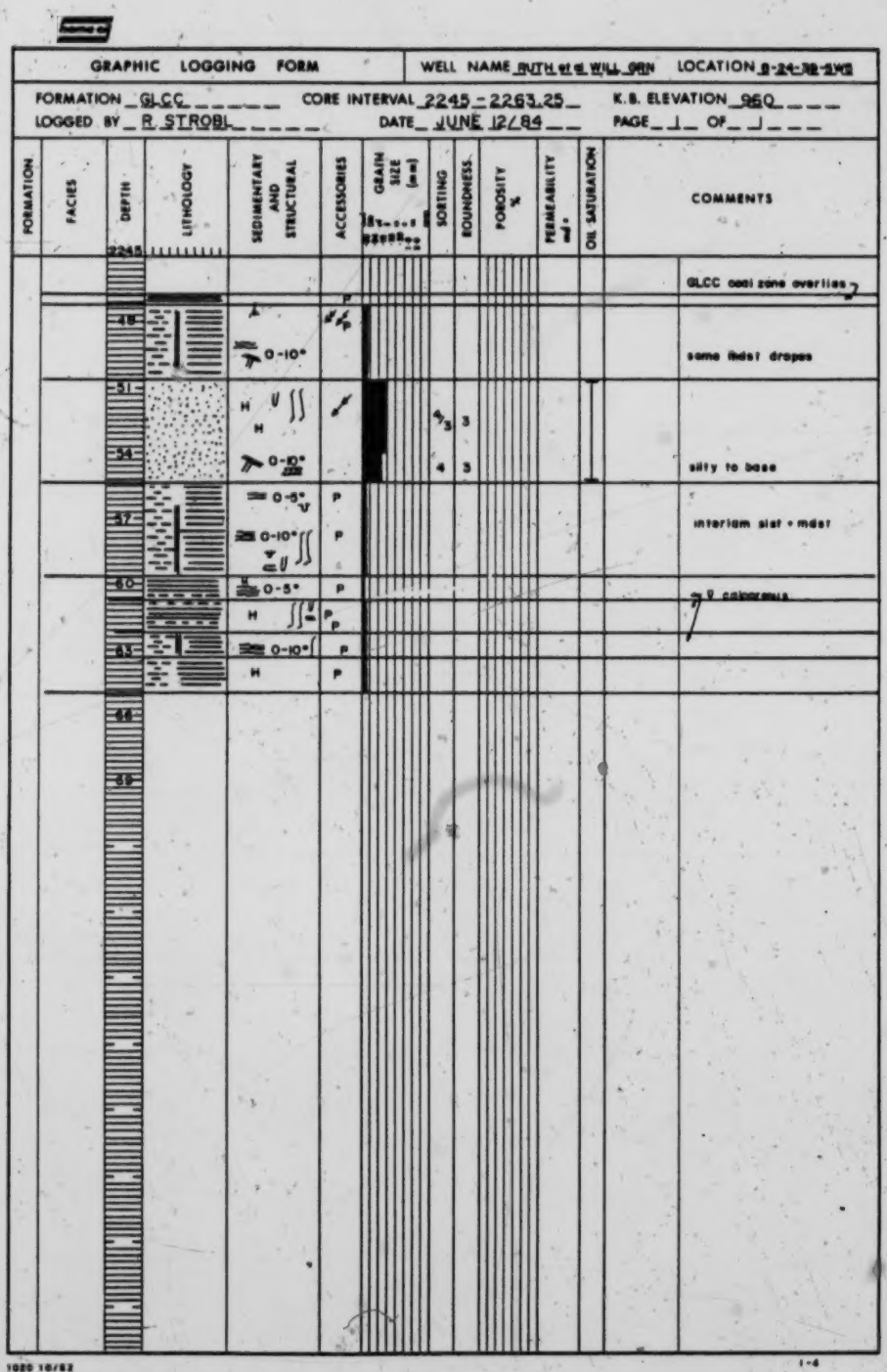
1020 10/82

1-6


GRAPHIC LOGGING FORM
WELL NAME DENISON LEAF
LOCATION 8-21-38-2W5
FORMATION GLCC
CORE INTERVAL 7480 - 7510
K.B. ELEVATION 3101
LOGGED BY R STROBL
DATE JUNE 11/84
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md.
OIL SATURATION
COMMENTS
7470
80
90
7500
10
20
H
H
U
P
0-10°
H
4/3
3
0-10°
V
aU
No γ log available
interlam slst., mdst.
vfg ss at base
1320 10/83
1-4

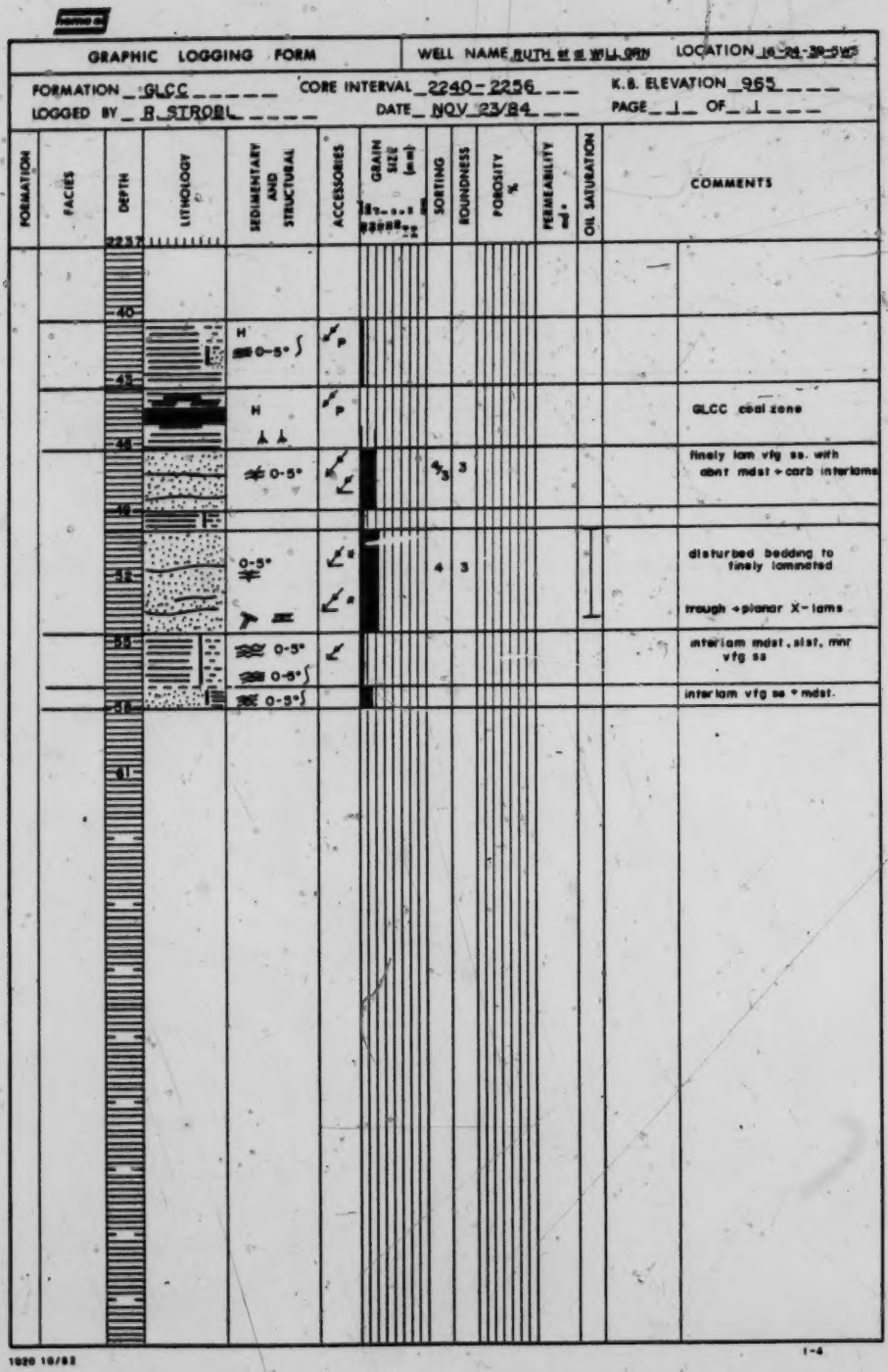

GRAPHIC LOGGING FORM
WELL NAME DEKAL B ST al WILLGm LOCATION 10-21-39-5W5
FORMATION GLCC
CORE INTERVAL 2285-2303
K.B. ELEVATION 947
LOGGED BY R. STROBL
DATE NOV 23/84
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md
OIL SATURATION
COMMENTS
2280
83
H
GLCC coal zone
88
0-5°
0-5°
interlam vfg ss, mdst + mnr slst.
93
H
0-5°
0-5°
4
3
abnt carb + mdst lams
finely laminated
92
0-5°
0-5°
interlam mdst + vfg ss
95
H
0-10°
1/3
3
distinctive sand marker
98
0-5°
H
0-5°
calc ΔT, ∫ kick.
2304
no oil staining to distort sheet ss structures
1026 10/82
1-4


GRAPHIC LOGGING FORM
WELL NAME Murphy Lastland
LOCATION 8-22-39-5W5
FORMATION GLCC
CORE INTERVAL 7545 - 7578
K.B. ELEVATION 3216
LOGGED BY R. STROBL
DATE JUNE 12/84
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md
OIL SATURATION
COMMENTS
7540
50
60
70
80
90
0-5°
0-5°
0-10°
GLCC coal zone
finely lam slst + mdst
dk. grey, massive
mor mdst lams
interlam slst, mdst.


GRAPHIC LOGGING FORM
WELL NAME RUTH et al WILL 9RN
LOCATION 9-24-38-5W3
FORMATION GLCC
CORE INTERVAL 2245 - 2263.25
K.B. ELEVATION 960
LOGGED BY R STROBL
DATE JUNE 12/84
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md
OIL SATURATION
COMMENTS
2245
GLCC coal zone overlies
48
0-10°
some fldst drapes
51
54
0-10°
silty to base
57
0-5°
0-10°
interlam slst + mdst
60
0-5°
9 calcareous
63
0-10°
66
69

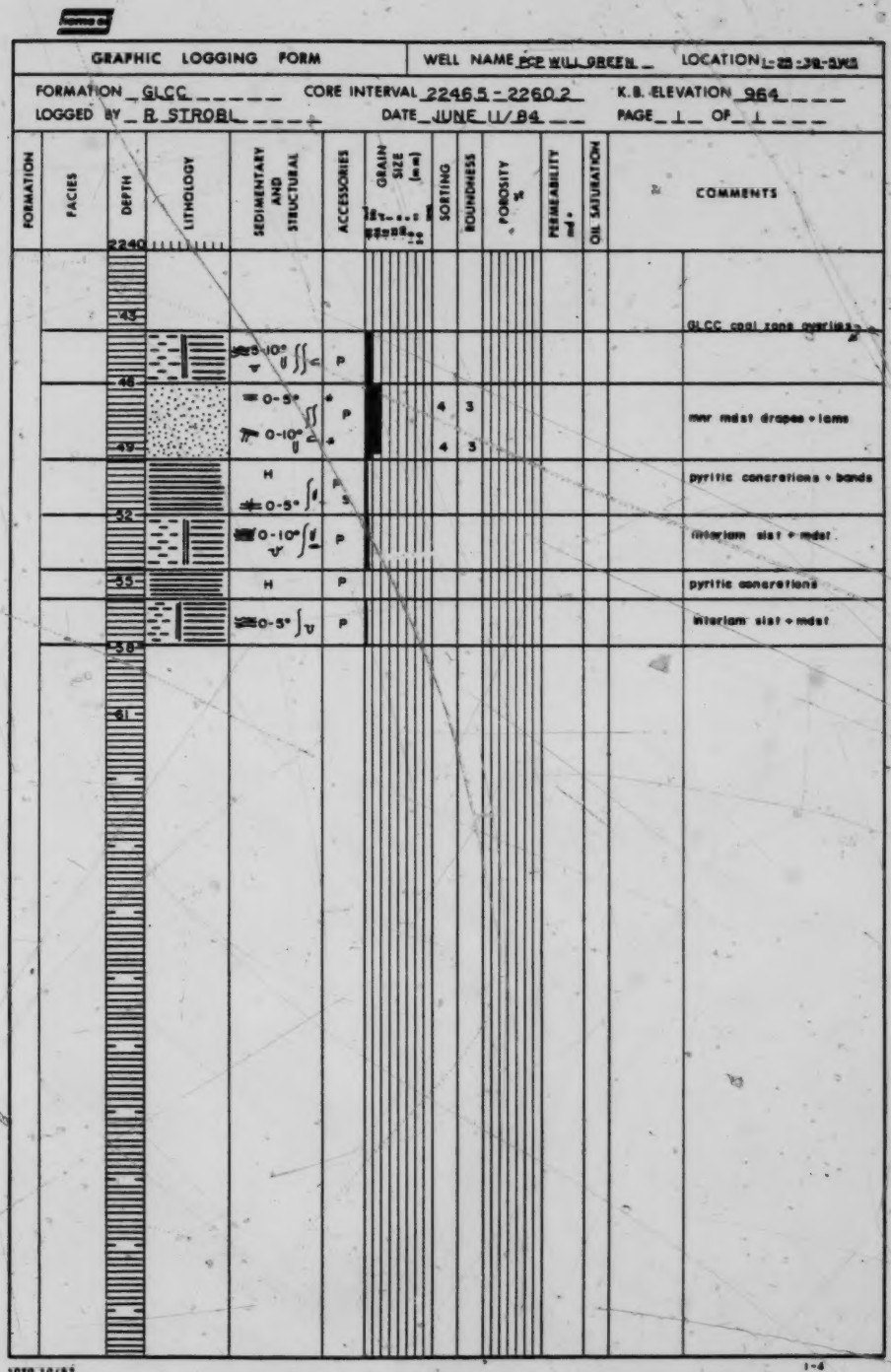
1020 10/82

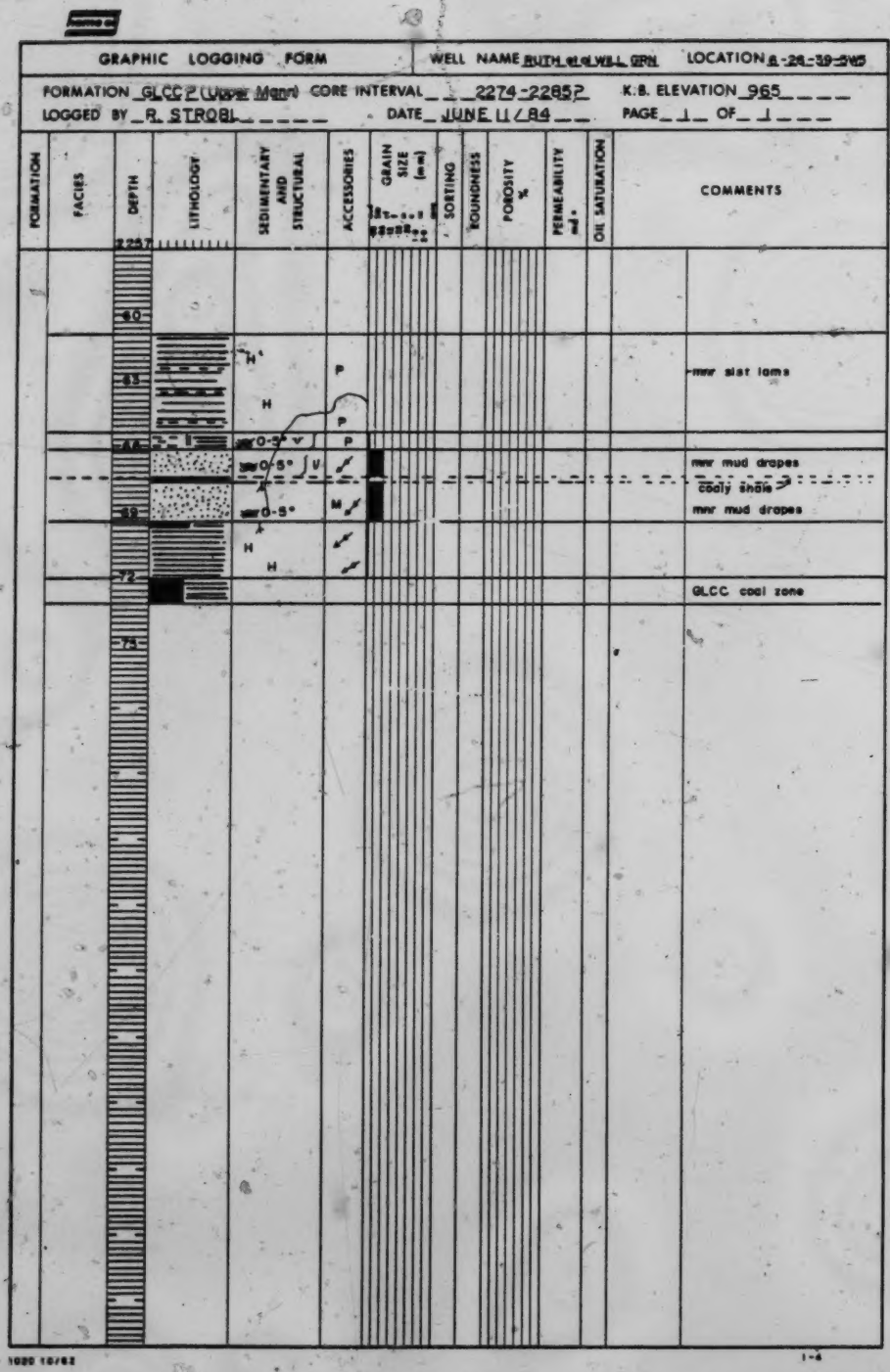
1-4

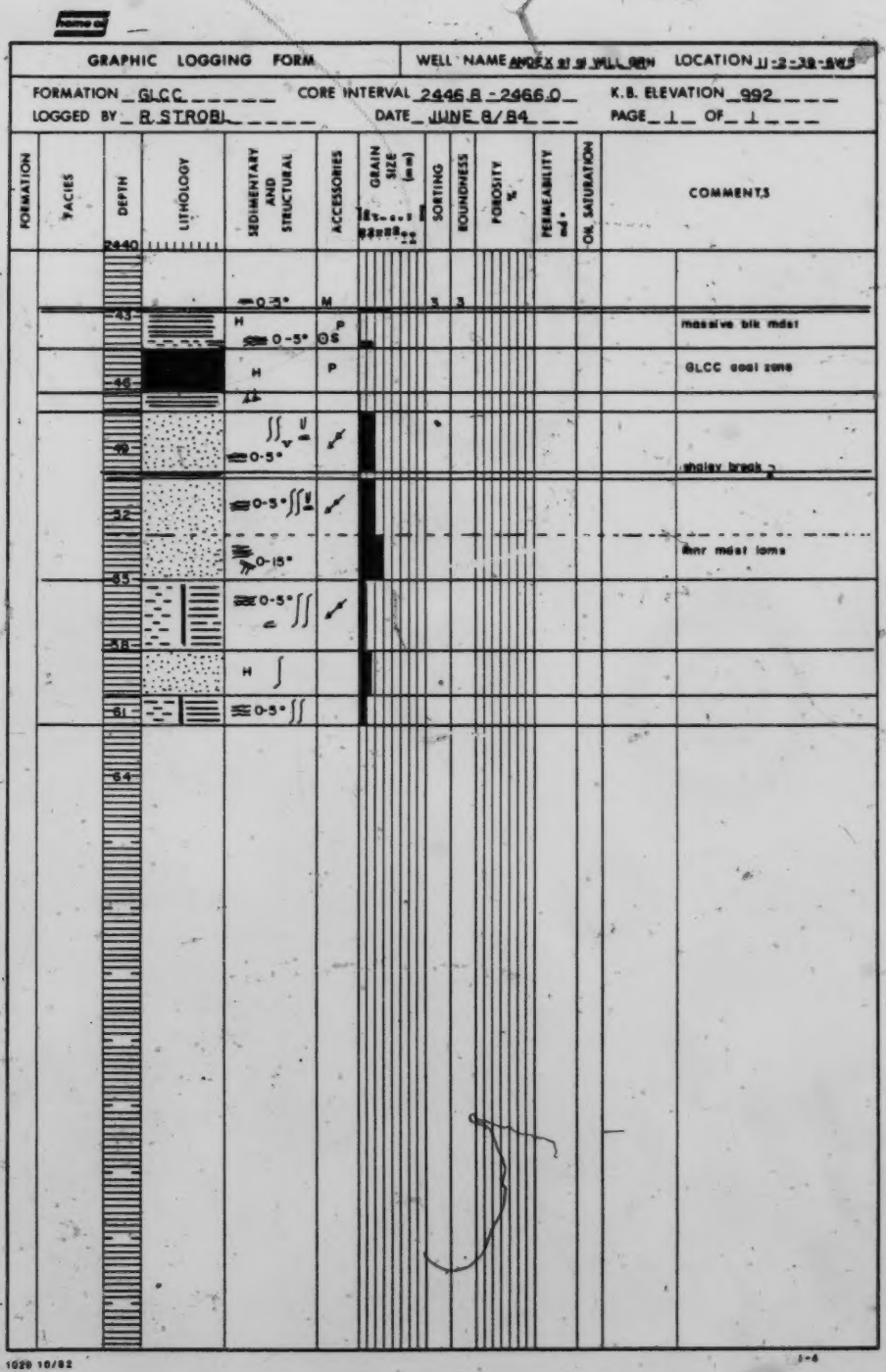

GRAPHIC LOGGING FORM
WELL NAME RUTH #1 E WILSON
LOCATION 16-24-30-5W5
FORMATION GLCC
CORE INTERVAL 2240-2256
K.B. ELEVATION 965
LOGGED BY R STROBL
DATE NOV 23/84
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md
OIL SATURATION
COMMENTS
2237
40
42
44
46
48
50
52
54
56
H
0-5°
GLCC coal zone
finely lam vfg ss. with
abnt mdst + carb interlams
disturbed bedding to
finely laminated
trough + planar X-lams
interlam mdst, slst, mnr
vfg ss
interlam vfg ss + mdst.

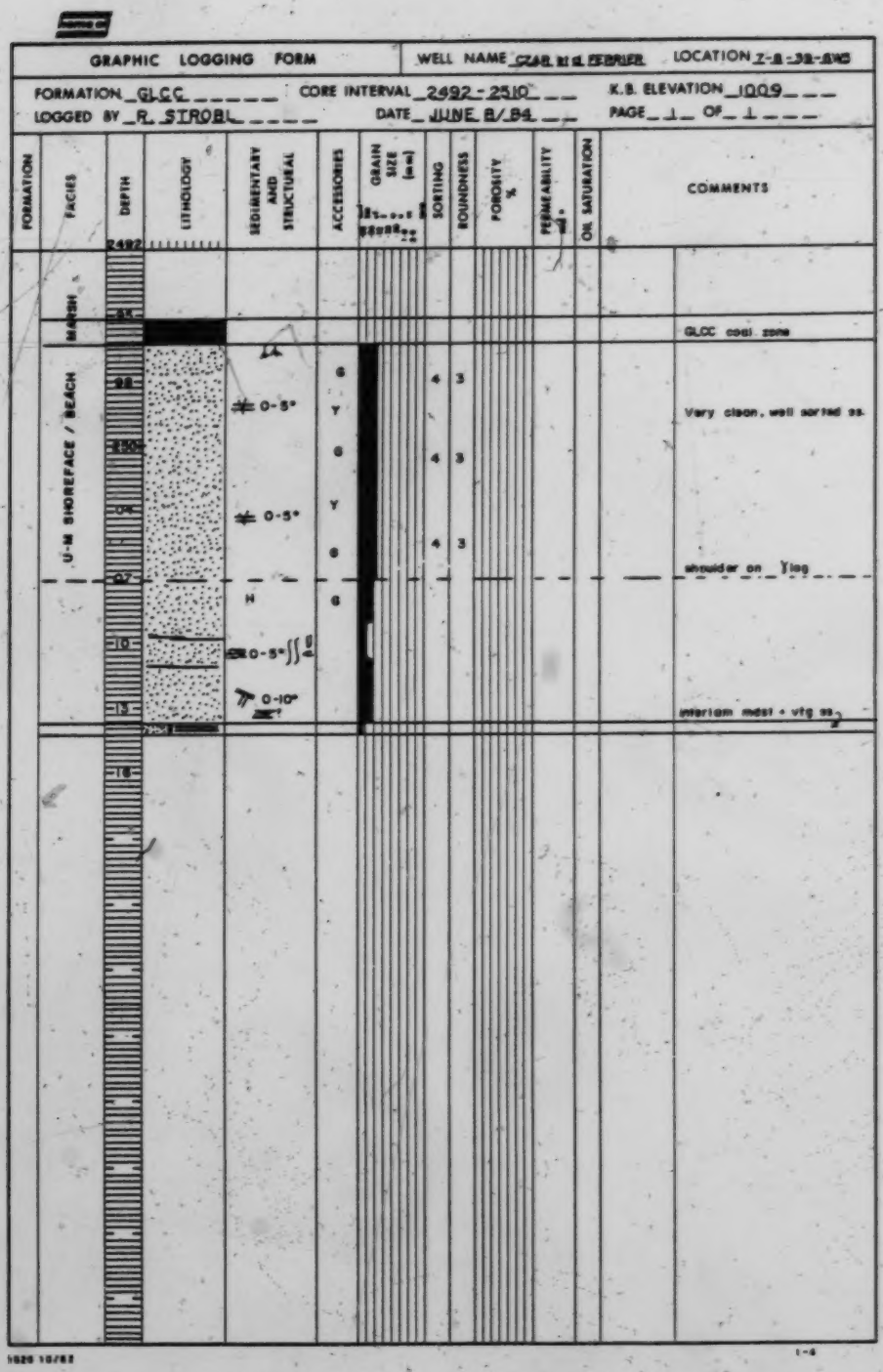
1020 10/83

1-4


GRAPHIC LOGGING FORM
WELL NAME BCP WILLGREEN
LOCATION
FORMATION GLCC
CORE INTERVAL 2246.5 - 2260.2
K.B. ELEVATION 964
LOGGED BY R. STROBL
DATE JUNE 11/84
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md.
OIL SATURATION
COMMENTS
2240
43
46
49
52
55
58
61
GLCC coal zone overlies
mm mdst drapes + lams
pyritic concretions + bands
interlam slst + mdst
pyritic concretions
interlam slst + mdst
1020 10/82
1-4


GRAPHIC LOGGING FORM
WELL NAME RUTH #1 CALWELL GRN
LOCATION 8-28-39-5W5
FORMATION GLCC 2 (Upper Mann)
CORE INTERVAL 2274-2285?
K.B. ELEVATION 965
LOGGED BY R. STROBL
DATE JUNE 11/84
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md
OIL SATURATION
COMMENTS
2257
60
63
66
69
72
75
mm slst lams
mm mud drapes
coaly shale
mm mud drapes
GLCC coal zone
0-5°
P
M
H
V


GRAPHIC LOGGING FORM
WELL NAME ANDEX 21 OF WELL GRN
LOCATION J-2-38-E43
FORMATION GLCC
CORE INTERVAL 2446.8 - 2466.0
K.B. ELEVATION 992
LOGGED BY R. STROBL
DATE JUNE 8/84
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md.
OIL SATURATION
COMMENTS
2440
43
44
49
52
55
58
61
64
massive blk mdst
GLCC coal zone
shaley break
thnr mdst lams
1020 10/82
J-4



GRAPHIC LOGGING FORM

WELL NAME CZAR #1 d FEBRILER LOCATION 7-8-32-8W5

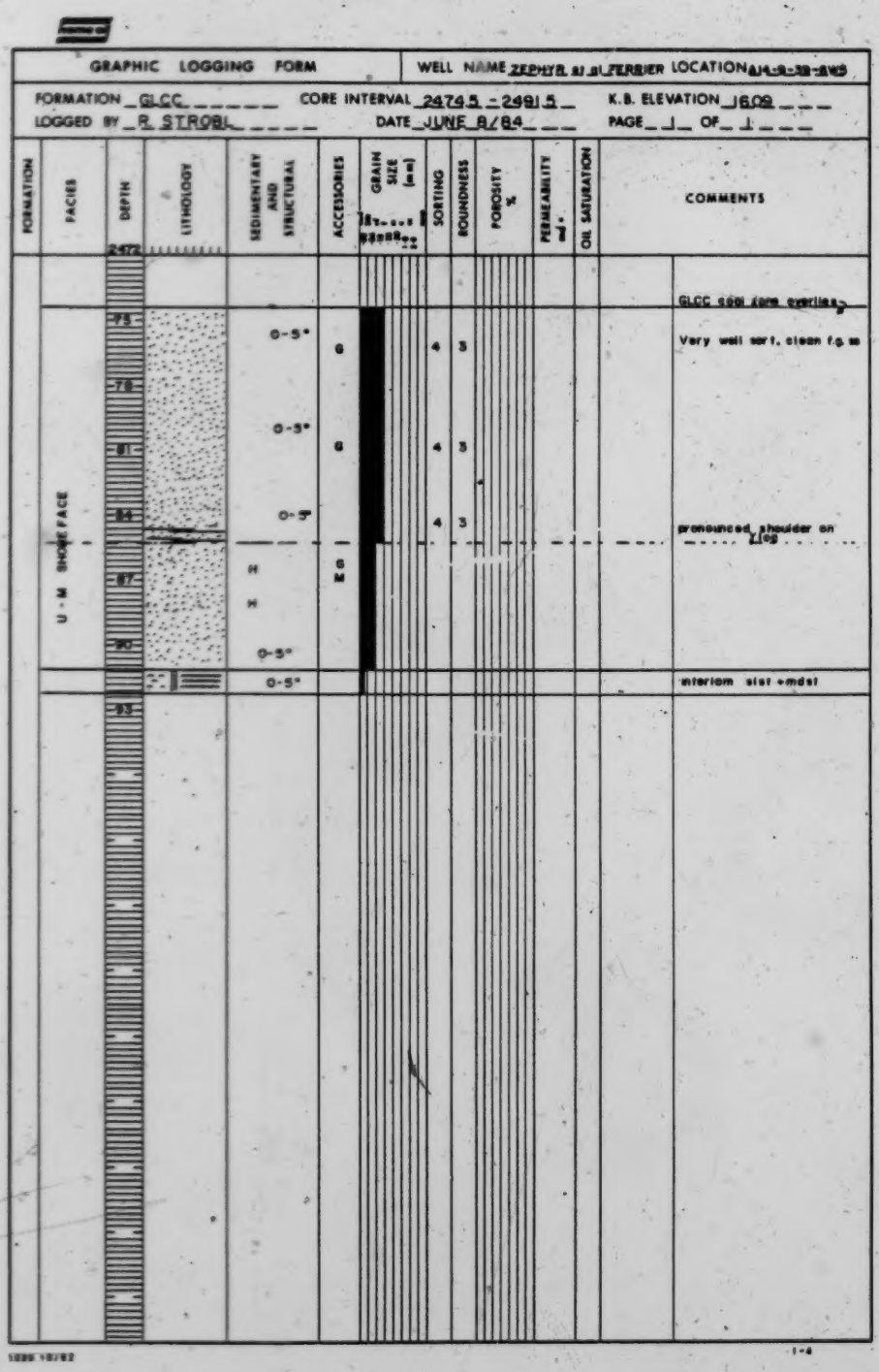
FORMATION GLCC CORE INTERVAL 2492 - 2510 K.B. ELEVATION 1009

LOGGED BY R. STROBL DATE JUNE 8/84 PAGE 1 OF 1

FORMATION	FACIES	DEPTH	LITHOLOGY	SEDIMENTARY AND STRUCTURAL	ACCESSORIES	GRAIN SIZE (mm)	SORTING	ROUNDNESS	POROSITY %	PERMEABILITY md.	OIL SATURATION	COMMENTS
		2492										
	MARSH											GLCC coal zone
	U-M SHOREFACE / BEACH			0-5°	G Y G		4 4	3 3				Very clean, well sorted ss.
				0-5°	Y G		4	3				
				H	G							shoulder on Ylog
				0-5°								
				0-10°								interlam mdst + vfg ss

1525 10/82

1-4



GRAPHIC LOGGING FORM

WELL NAME ZEPHYR #1 @ LAFFERIER LOCATION A14-9-38-8W5

FORMATION GLCC CORE INTERVAL 2474.5 - 2491.5 K.B. ELEVATION 1609

LOGGED BY R. STROBL DATE JUNE 8/84 PAGE 1 OF 1

FORMATION | FACIES | DEPTH | LITHOLOGY | SEDIMENTARY AND STRUCTURAL | ACCESSORIES | GRAIN SIZE (mm) | SORTING | ROUNDNESS | POROSITY % | PERMEABILITY md. | OIL SATURATION | COMMENTS

2472

GLCC sand zone overlies

75

0-5°

G

4 3

Very well sort, clean f.g. ss

78

0-5°

G

4 3

81

0-5°

4 3

pronounced shoulder on Log

U - M SHORE FACE

84

H

H

Mc

87

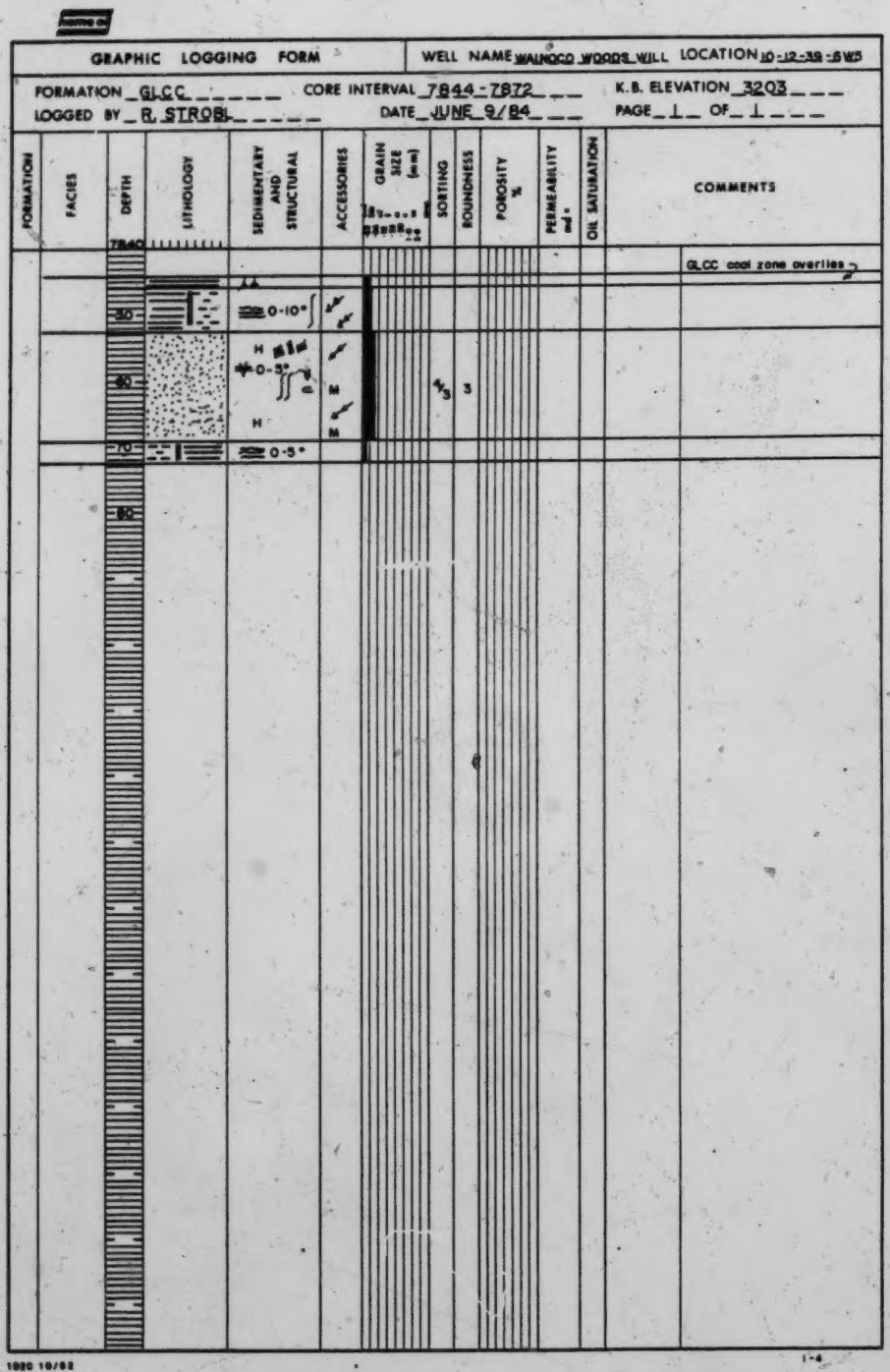
0-5°

90

0-5°

interlam silst + mdst

93


GRAPHIC LOGGING FORM
WELL NAME WALNOCO WOODS WILL LOCATION 10-12-39-5W5
FORMATION GLCC
CORE INTERVAL 7844-7872
K.B. ELEVATION 3203
LOGGED BY R. STROBL
DATE JUNE 9/84
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md
OIL SATURATION
COMMENTS
7840
GLCC coal zone overlies
50
0-10°
60
0-5°
H
M
H
M
4/3
3
70
0-5°
80

1020 10/82

1-4

GRAPHIC LOGGING FORM — WELL NAME WAINOCO #1 of WILL OR — LOCATION 10-13-38-8W5

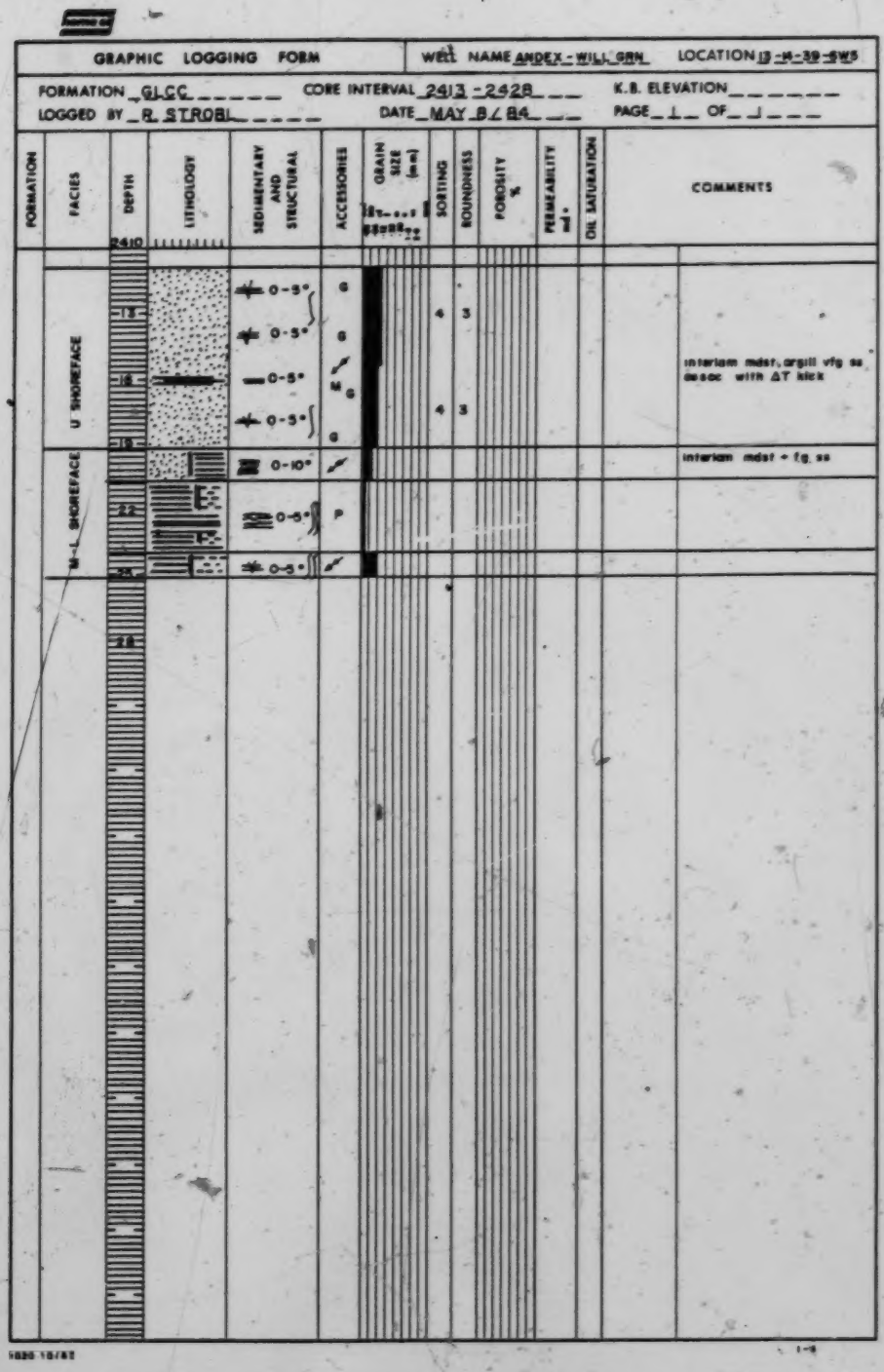
FORMATION GLCC — CORE INTERVAL 7799 - 7832 — K.B. ELEVATION 3208

LOGGED BY R. STROBL — DATE MAY 9/84 — PAGE 1 OF 1

FORMATION	FACIES	DEPTH	LITHOLOGY	SEDIMENTARY AND STRUCTURAL	ACCESSORIES	GRAIN SIZE (mm)	SORTING	ROUNDNESS	POROSITY %	PERMEABILITY md.	OIL SATURATION	COMMENTS
		7799										
				H	P							GLCC coal zone
	Lagoonal ?	7800		0-5°	P							silty mdst with slst interlams
		10		0-5°	M							
		20		0-5°	M							
		30		0-5°	P							slst interlams
		40										

1820 10/82

1-4



GRAPHIC LOGGING FORM

WELL NAME ANDEX - WILLGRN LOCATION 13-14-39-5W5

FORMATION GLCC CORE INTERVAL 2413 - 2428 K.B. ELEVATION

LOGGED BY R. STROBL DATE MAY 8/84 PAGE 1 OF 1

FORMATION | FACIES | DEPTH | LITHOLOGY | SEDIMENTARY AND STRUCTURAL | ACCESSORIES | GRAIN SIZE (mm) | SORTING | ROUNDNESS | POROSITY % | PERMEABILITY md | OIL SATURATION | COMMENTS

2410

U SHOREFACE

0-5°
0-5°
0-5°
0-5°

G
G
G
G

4 3
4 3

interlam mdst, argill vfg ss
assoc with ΔT kick

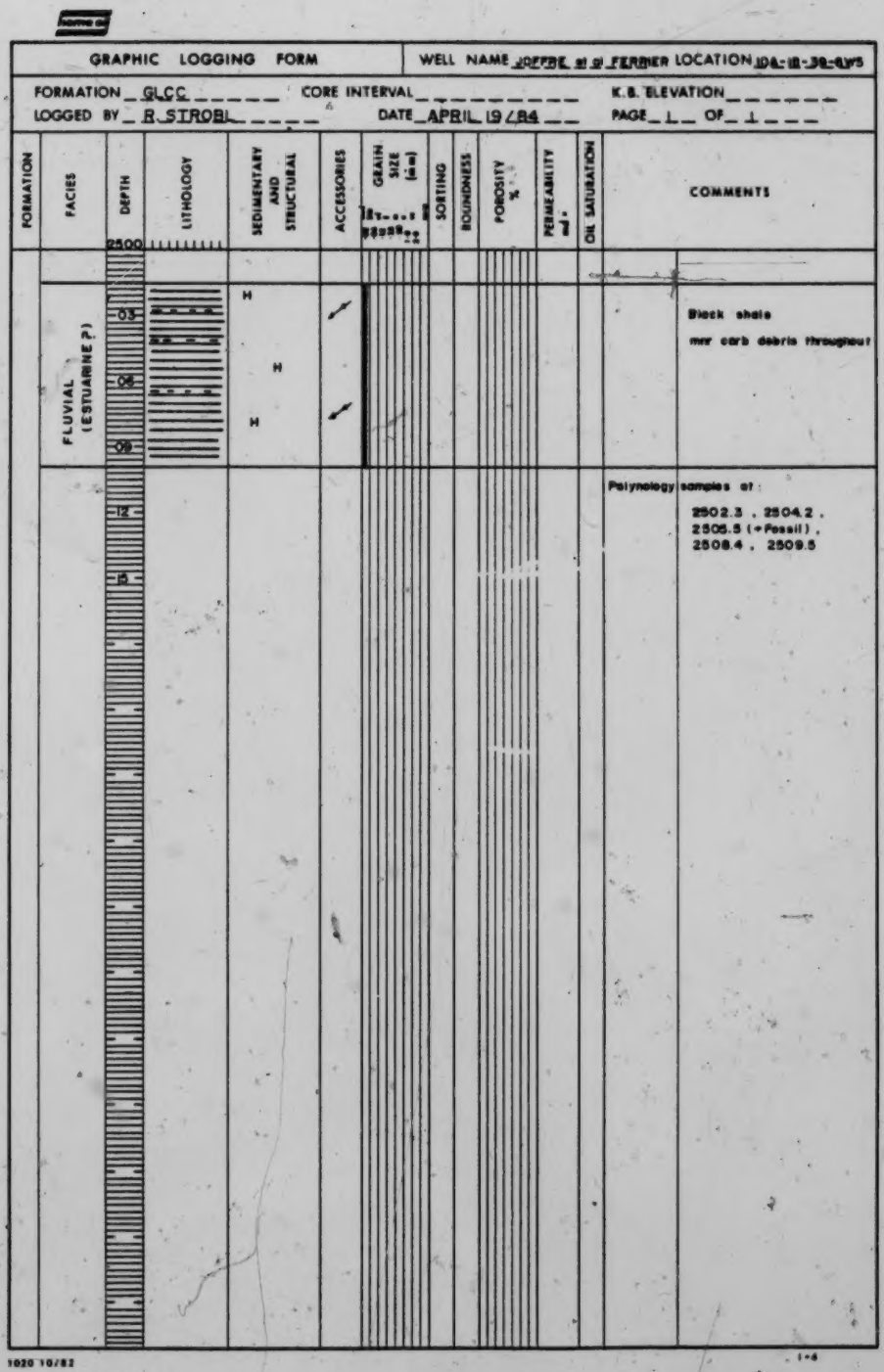
M-L SHOREFACE

0-10°
0-5°
0-5°

P

interlam mdst + fg ss

2428



GRAPHIC LOGGING FORM

WELL NAME JOFFRE et al FERRIER LOCATION 104-B-30-6W5

FORMATION GLCC CORE INTERVAL K.B. ELEVATION

LOGGED BY R. STROBL DATE APRIL 19/84 PAGE 1 OF 1

FORMATION | FACIES | DEPTH | LITHOLOGY | SEDIMENTARY AND STRUCTURAL | ACCESSORIES | GRAIN SIZE (mm) | SORTING | ROUNDNESS | POROSITY % | PERMEABILITY md. | OIL SATURATION | COMMENTS

2500

FLUVIAL (ESTUARINE ?)

03

06

09

12

15

H

H

H

Black shale

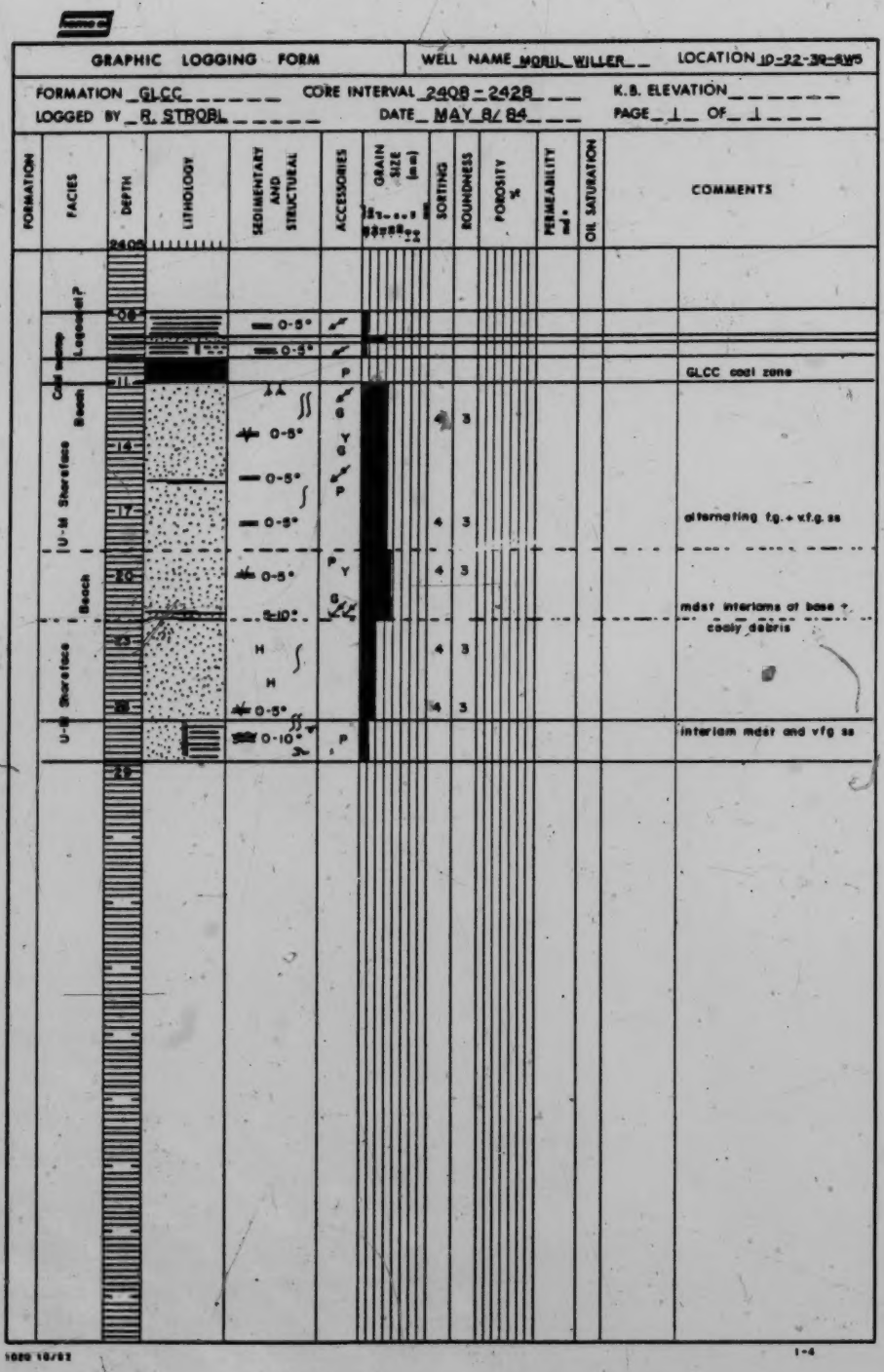
mnr carb debris throughout

Palynology samples at :

2502.3 , 2504.2 ,
2505.5 (→Fossil) ,
2508.4 , 2509.5

1020 10/82

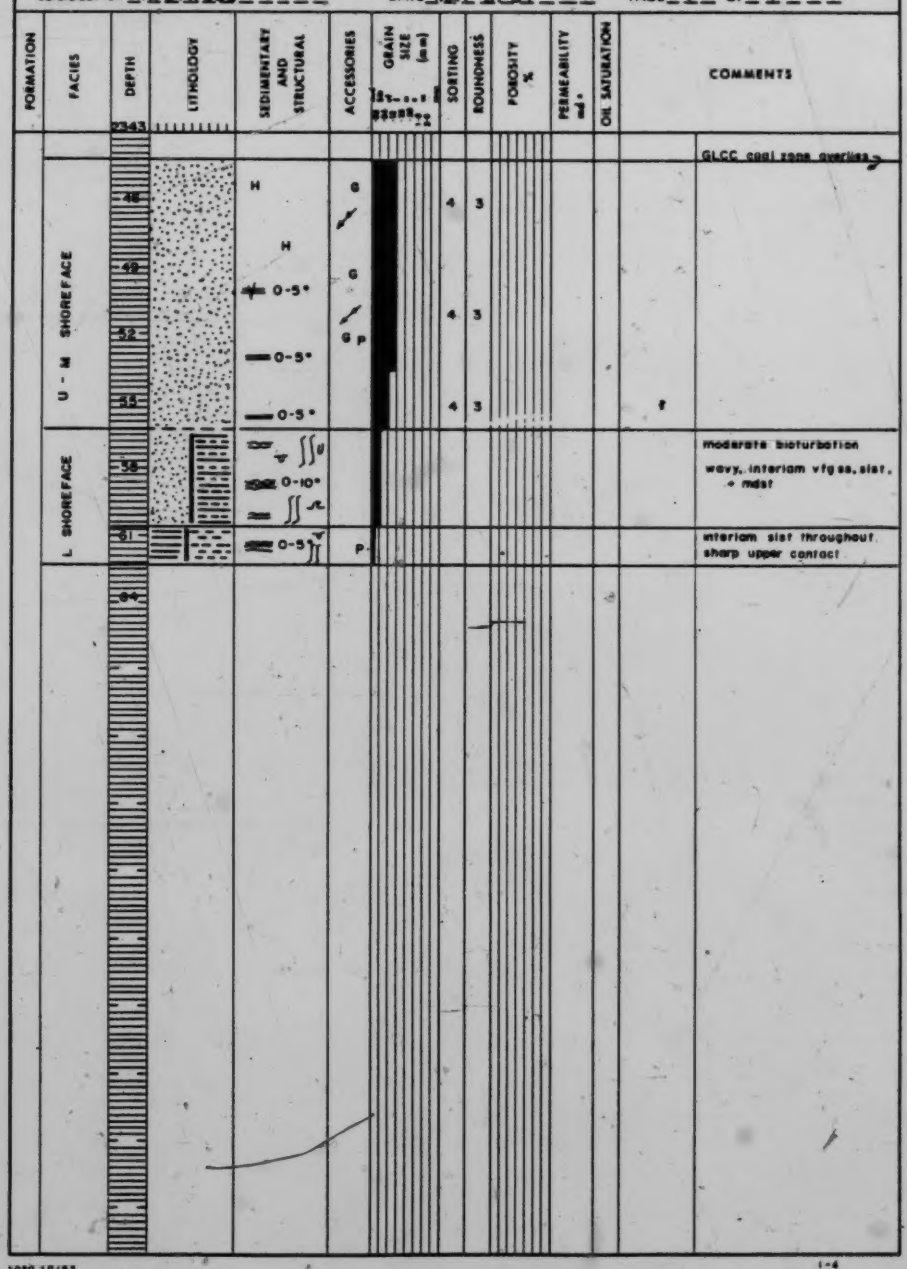
1-6


GRAPHIC LOGGING FORM
WELL NAME MORIL WILLER
LOCATION 10-22-38-6W5
FORMATION GLCC
CORE INTERVAL 2408 - 2428
K.B. ELEVATION
LOGGED BY R. STROBL
DATE MAY 8/84
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md
OIL SATURATION
COMMENTS
2405
Coal zone
Beach
U-M Shoreface
Beach
U-M Shoreface
U-M
0-5°
0-10°
GLCC coal zone
alternating f.g. + v.f.g. ss
mdst interlams at base + coaly debris
interlam mdst and vfg ss
1020 10/82
1-4

GRAPHIC LOGGING FORM — WELL NAME MOBIL WELL #RRL — LOCATION 7-25-38-6W5

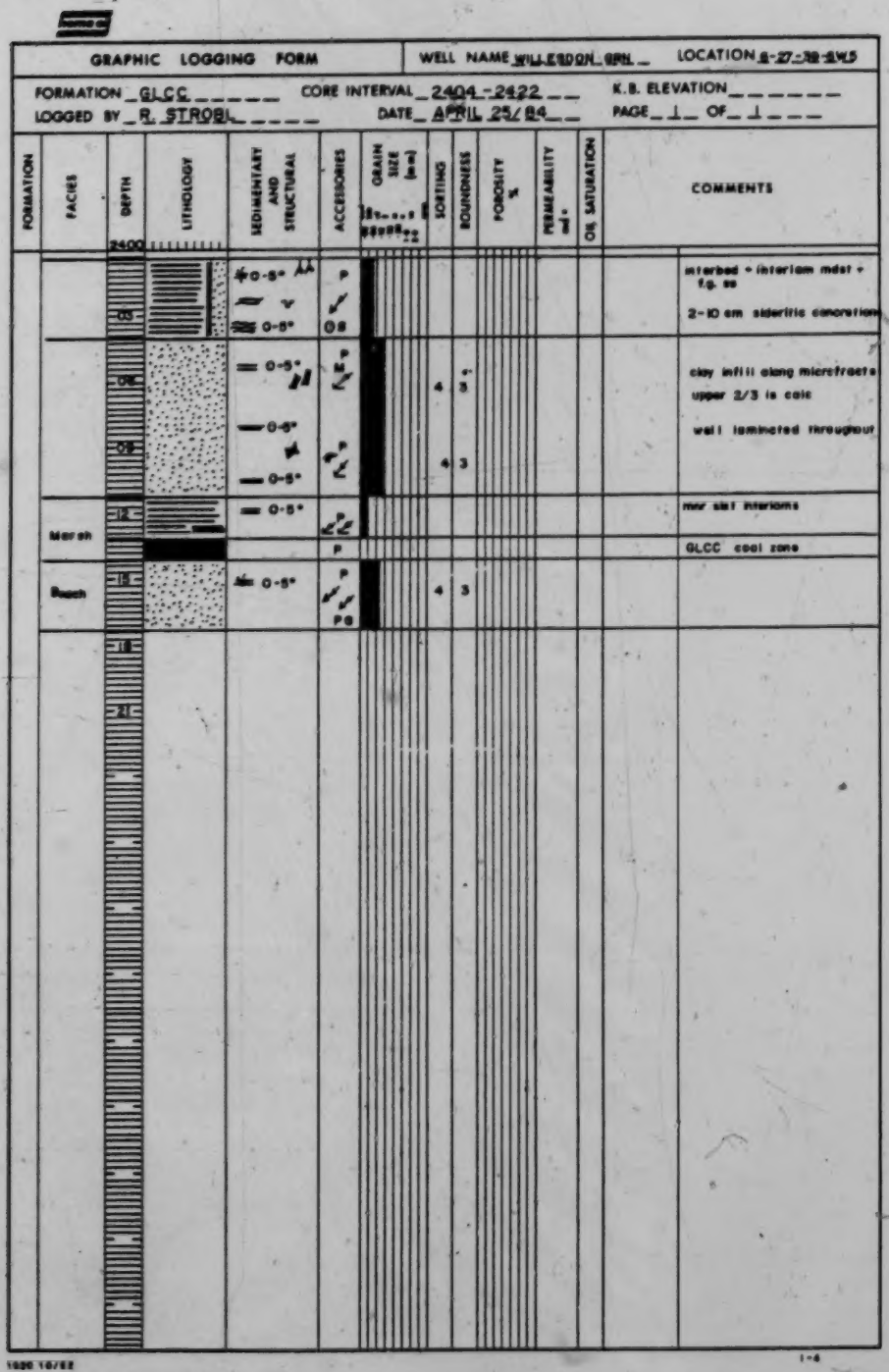
FORMATION GLCC — CORE INTERVAL 2343.5 - 2361.5 — K.B. ELEVATION

LOGGED BY R. STROBL — DATE MAY 8/84 — PAGE 1 OF 1



1020 10/82

1-4



GRAPHIC LOGGING FORM

WELL NAME WILLESDON GPH. LOCATION 8-27-38-5W5

FORMATION GLCC CORE INTERVAL 2404-2422 K.B. ELEVATION

LOGGED BY R. STROBL DATE APRIL 25/84 PAGE 1 OF 1

FORMATION | FACIES | DEPTH | LITHOLOGY | SEDIMENTARY AND STRUCTURAL | ACCESSORIES | GRAIN SIZE (mm) | SORTING | ROUNDNESS | POROSITY % | PERMEABILITY md+ | OIL SATURATION | COMMENTS

2400

Marsh

Beach

COMMENTS:

interbed + interlam mdst + f.g. ss

2-10 cm sideritic concretions

clay infill along microfracts

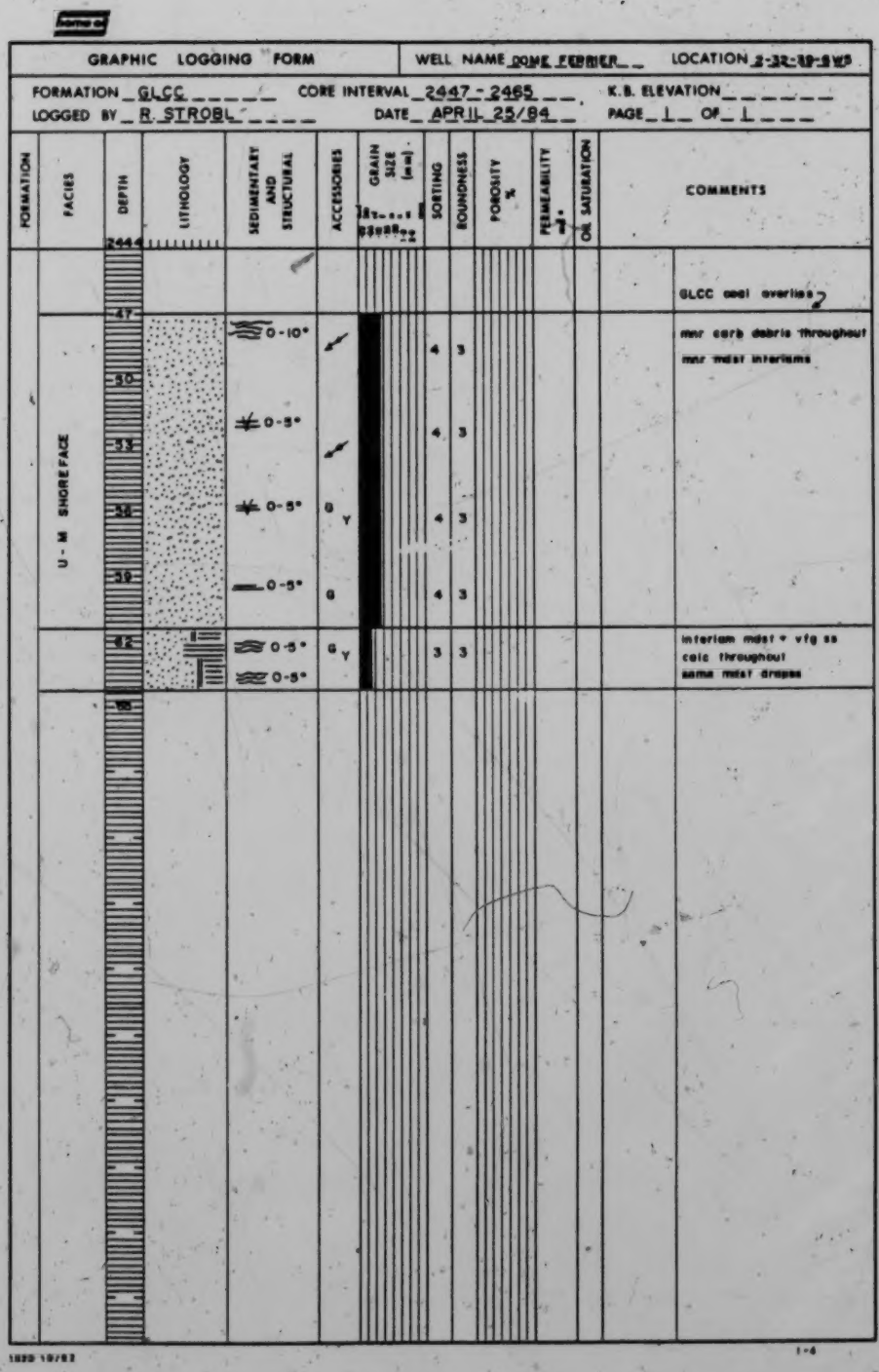
upper 2/3 is calc

well laminated throughout

mm shell interlams

GLCC cool zone

1-4



GRAPHIC LOGGING FORM

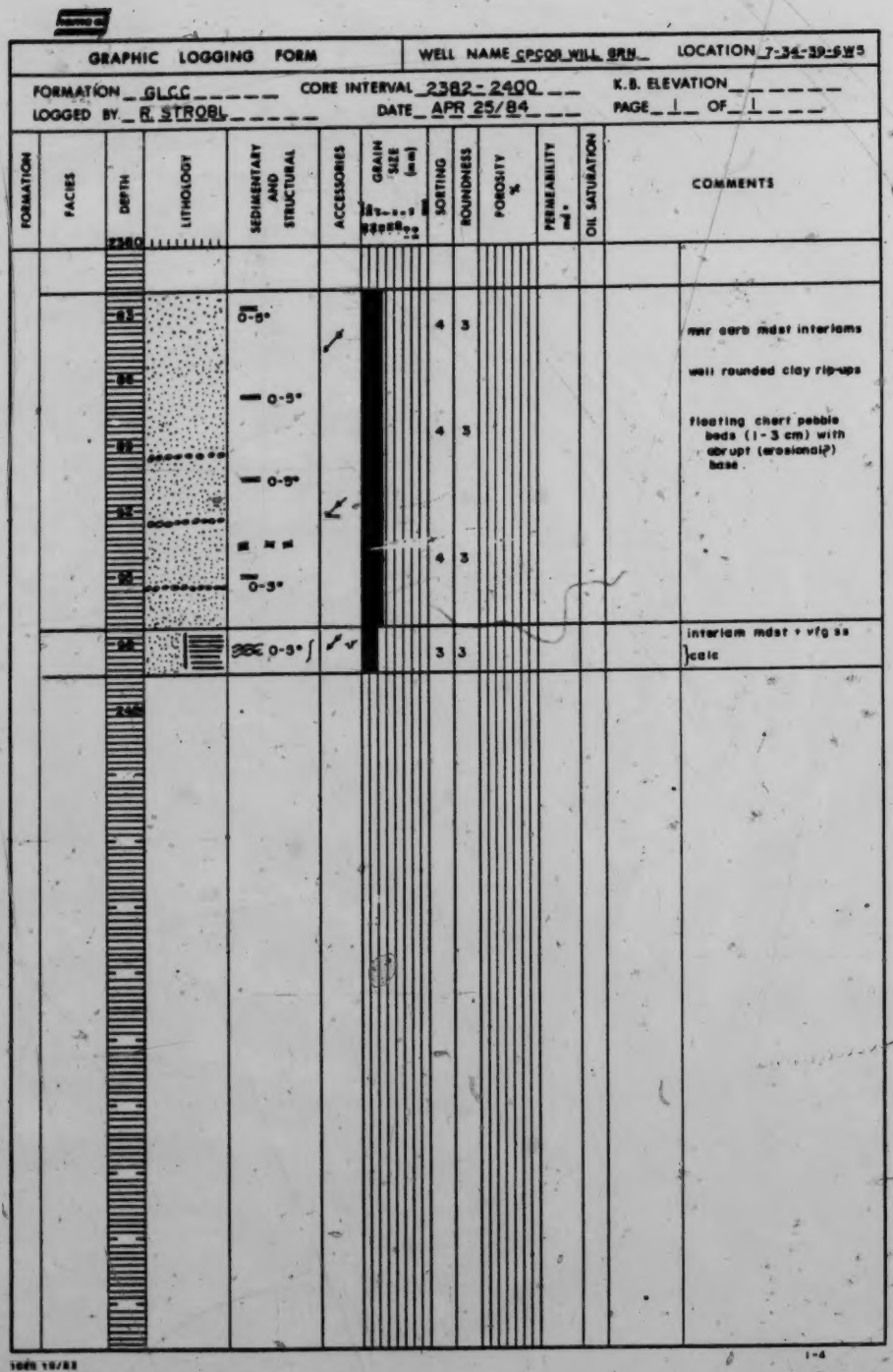
WELL NAME DOME FERRIER LOCATION 2-32-19-9 W5

FORMATION GLCC CORE INTERVAL 2447 - 2465 K.B. ELEVATION

LOGGED BY R. STROBL DATE APRIL 25/84 PAGE 1 OF 1

1829 10/82

1-6



GRAPHIC LOGGING FORM

WELL NAME CPC09 WILL 8RH LOCATION 7-34-39-6W5

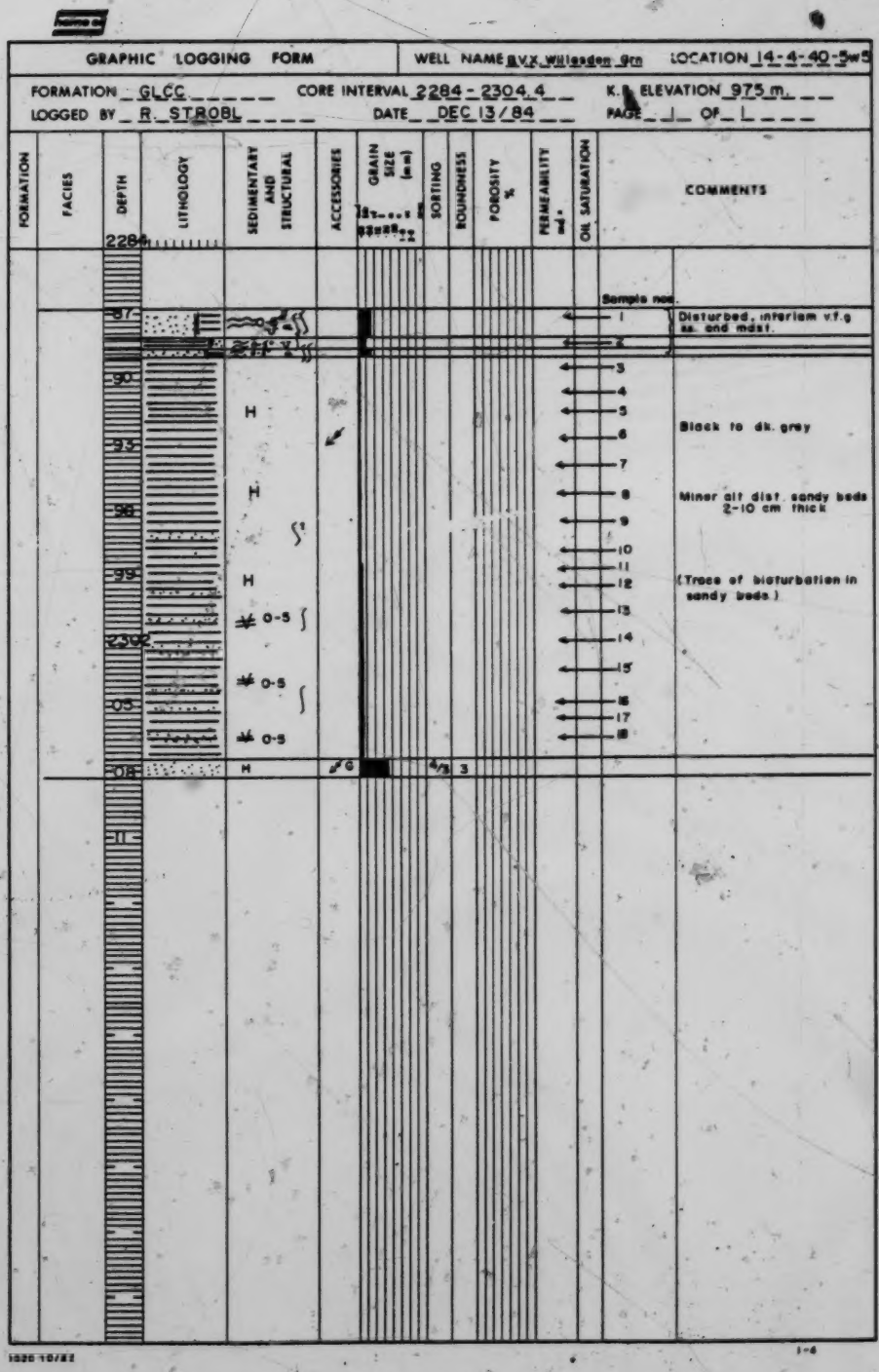
FORMATION GLCC CORE INTERVAL 2382 - 2400 K.B. ELEVATION

LOGGED BY R. STROBL DATE APR 25/84 PAGE 1 OF 1

FORMATION	FACIES	DEPTH	LITHOLOGY	SEDIMENTARY AND STRUCTURAL	ACCESSORIES	GRAIN SIZE (mm)	SORTING	ROUNDNESS	POROSITY %	PERMEABILITY md	OIL SATURATION	COMMENTS
		2380										
				0-5°			4	3				mnr carb mdst interlams
												well rounded clay rip-ups
				0-5°			4	3				floating chert pebble beds (1-3 cm) with abrupt (erosional?) base.
				0-5°								
				0-5°			4	3				
				0-5°			3	3				interlam mdst + vfg ss } calc
		2400										

1685 10/83

1-4


GRAPHIC LOGGING FORM
WELL NAME BVX Willesden 9cn
LOCATION 14-4-40-5w5
FORMATION GLCC
CORE INTERVAL 2284 - 2304.4
K.B. ELEVATION 975 m
LOGGED BY R. STROBL
DATE DEC 13/84
PAGE 1 OF 1
FORMATION
FACIES
DEPTH
LITHOLOGY
SEDIMENTARY AND STRUCTURAL
ACCESSORIES
GRAIN SIZE (mm)
SORTING
ROUNDNESS
POROSITY %
PERMEABILITY md.
OIL SATURATION
COMMENTS
2284
Sample nos.
1
Disturbed, interlam v.f.g ss. and mdst.
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Black to dk. grey
Minor silt dist. sandy beds 2-10 cm thick
(Trace of bioturbation in sandy beds)
H
0-5
2302
2308
2311
SORTING 4/3
ROUNDNESS 3

Appendix B

Palynology

(Courtesy of Dr. C. Singh, Alberta Research Council, Edmonton)

	14-4-40-5W5	2306.8m	2301.1m	2294.5m	2288.4m	10-35-38-4W5	7190 ft	7-34-38-4W5	7250.5 ft	7240 ft	7231 ft	4-27-38-4W5	7391 ft	7371 ft	7363 ft	2-19-39-4W5	7291.1 ft	7290.6 ft	7271.2 ft	7260.3 ft
DINOFLAGELLATES																				
Bacchidinium polypes (Cookson and Eisenack) Davey, 1979					1													3		
Chlamydophorella nyei Cookson and Eisenack, 1958											1									
Cleistospaeridium multispinosum (Singh) Brideaux, 1971		1																		
Cyclonephelium distinctum Deflandre and Cookson, 1955					1															
Cyclonephelium hirtellum (Alberti) Davey, 1978													1					7		
Dingodinium cerviculum Cookson and Eisenack, 1958						no recovery					1				no recovery			1	no recovery	no recovery
Muderongia staurota Sarjeant, 1966																		1		
Muderongia sp. A		4									6									
Muderongia sp. B		2								1	1		3	1						
Muderongia spp.		1	1	1			1			7								1		
Odontochitina operculata (O. Wetzel) Deflandre and Cookson, 1955				2			1				2						2	2		
Oligosphaeridium complex (White) Davey and Williams, 1966																		2		
Palaeoperidinium cretaceum Pocock, 1962													4				2	11		
Pareodinia sp.											1									
Pseudoceratium nudum Gocht, 1957																		1		
ACRITARCHS																				
Pterospermella aureolata (Cookson and Eisenack) Eisenack, 1972																		1		
Veryhachium lairdi (Deflandre) Deunff, 1954			2	7	1		6				4									
Veryhachium reductum (Deunff) Jekhowsky, 1961				1																

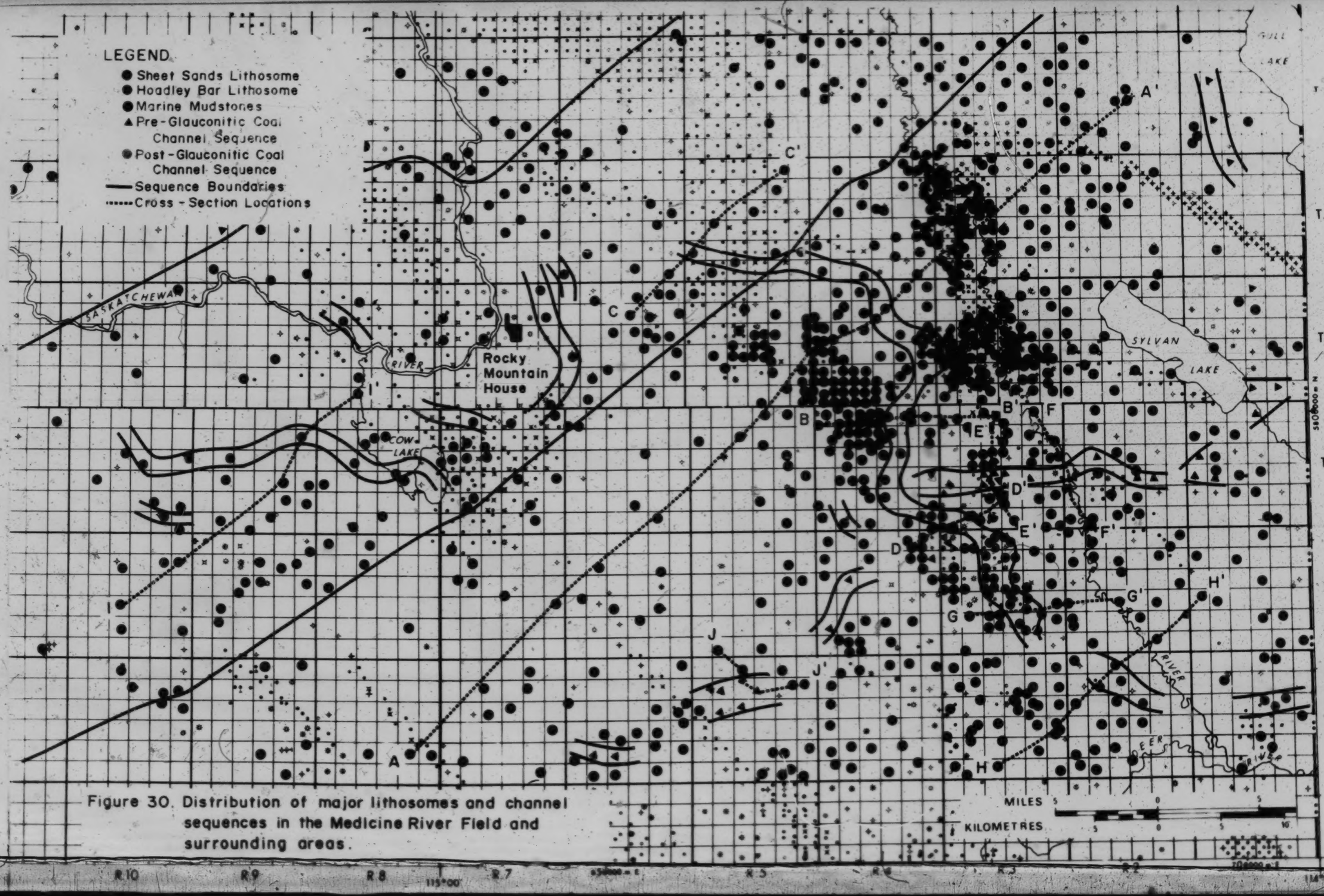


Figure 30. Distribution of major lithosomes and channel sequences in the Medicine River Field and surrounding areas.

A (Southwest)

7-11-36-8W5
K.B. 3794'

10-13-37-7W5
K.B. 3526'

10-2-38-6W5
K.B. 1004m

11-28-38-5W5
K.B. 987m

4-18-39-4W5
K.B. 3127'

G.R. Sonic 16 Km G.R. Sonic 10 Km G.R. Sonic 8.5 Km G.R. Sonic 6 Km G.R. Sonic 5 Km

Medicine River Coal (Datum)

Glauconitic Coal Zone

Glauconitic Sheet Sands

Calcareous Marker

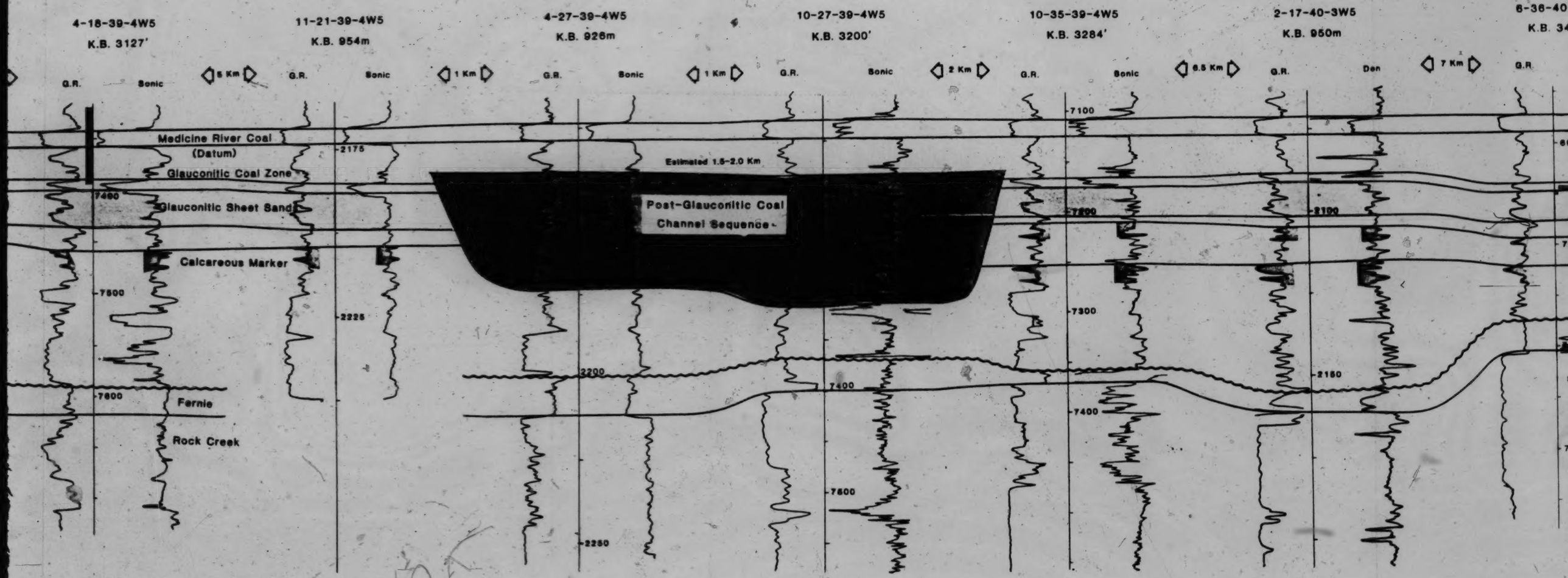
Fernie

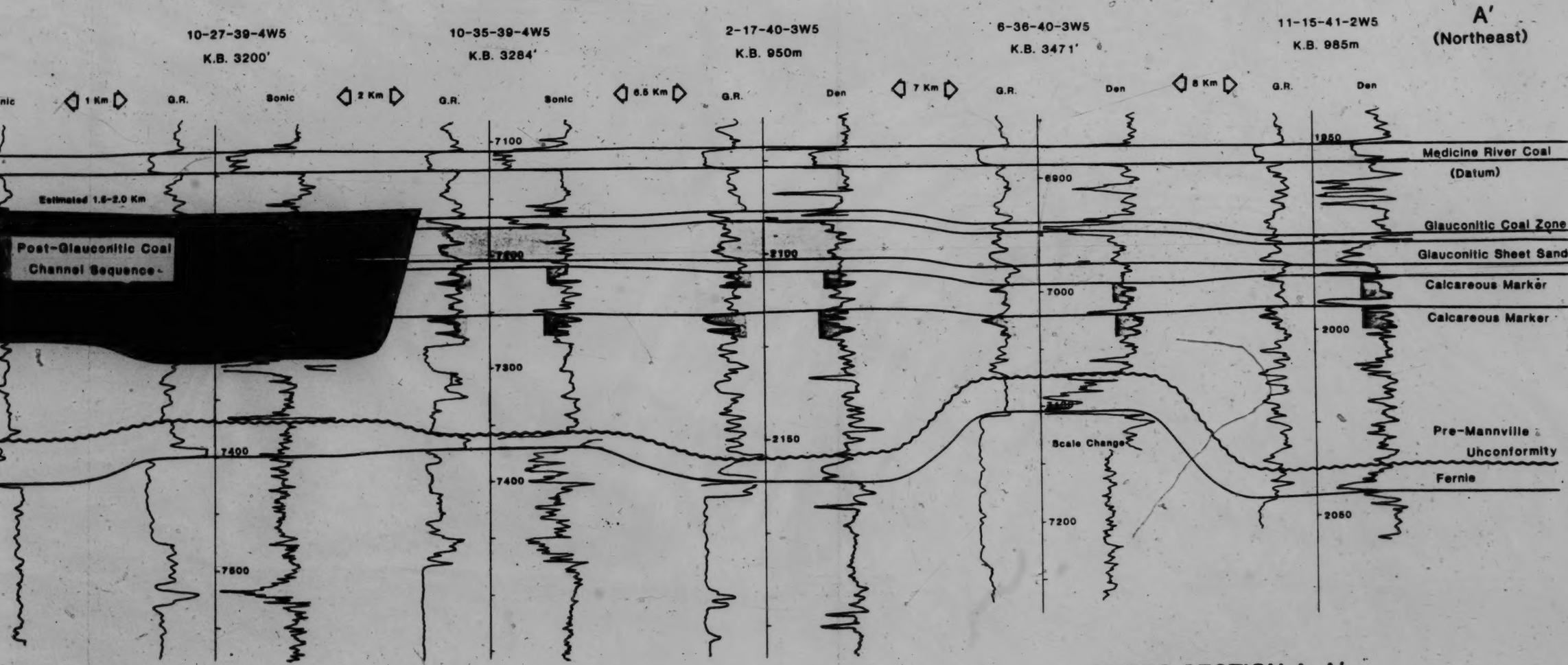
Rock Creek

Pre-Mannville Unconformity

Scale Change

9900
10000
10100
10200
9000
9100
9200
2500
2650
2600
2400
7400
7500
7600


4-18-39-4W5
K.B. 3127'
11-21-39-4W5
K.B. 954m
4-27-39-4W5
K.B. 926m
10-27-39-4W5
K.B. 3200'
10-35-39-4W5
K.B. 3284'
2-17-40-3W5
K.B. 950m
6-36-40
K.B. 34
G.R.
Sonic
Den
5 Km
1 Km
2 Km
6.5 Km
7 Km
Medicine River Coal
(Datum)
Glauconitic Coal Zone
Glauconitic Sheet Sand
Calcareous Marker
Fernie
Rock Creek
Estimated 1.5-2.0 Km
Post-Glauconitic Coal
Channel Sequence
7100
7200
7300
7400
7500
7600
7400
7500
2175
2225
2200
2250
2100
2150



CROSS-SECTION A-A'

R. Strobl
April, 1986.

B
(West)

4-31-38-4W5	2-33-38-4W5	4-34-38-4W5	7 34-38-4W5	10-35-38-4W5
K.B. 3276'	K.B. 3202'	K.B. 3185'	K.B. 3161'	K.B. 3182'

G.R. Sonic — 4 Km — G.R. Sonic — 0.5 Km — G.R. Sonic — 0.5 Km — G.R. Sonic — 0.5 Km — G.R. Sonic — 0.5 Km

Medicine River Coal

(Datum)

Glauc Coal Zone

Glauc Sheet Sands

Calcareous Marker

Calcareous Marker

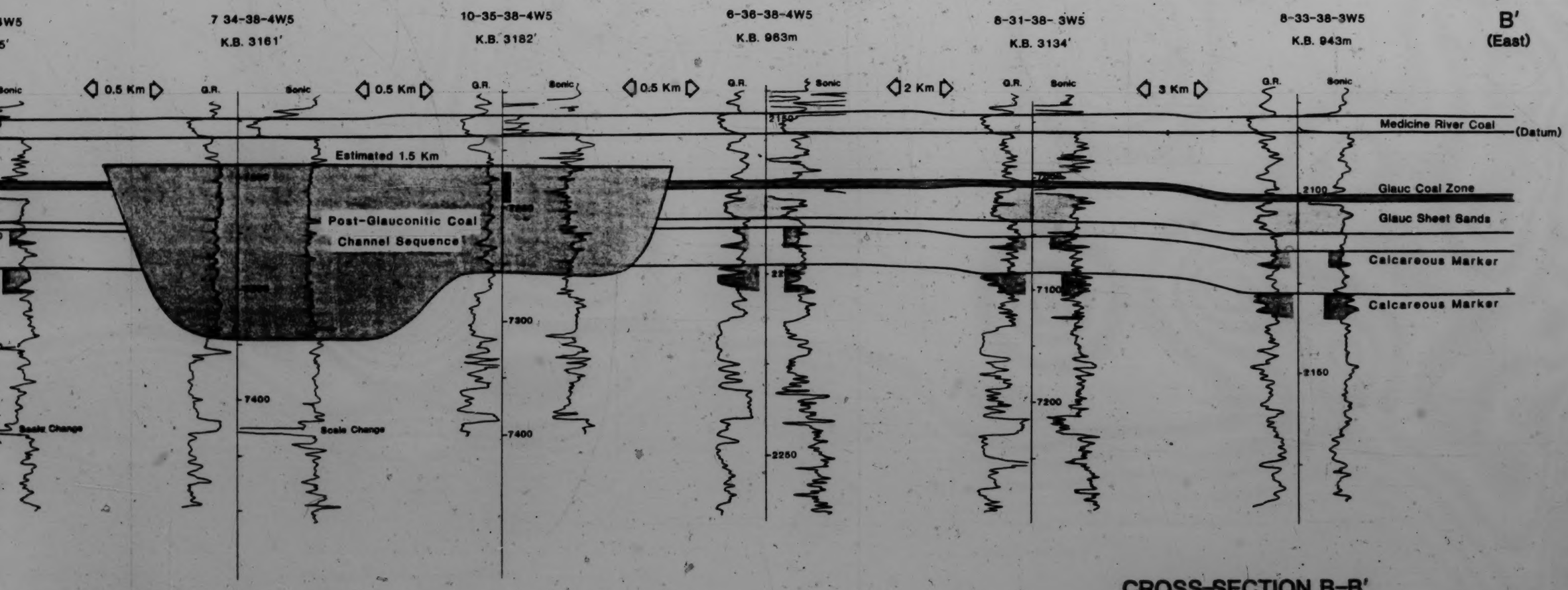
Estimated 1.5 Km

Post-Glauconitic Coal Channel Sequence

7500 7300 7200 7300 7400 7300 7400 7300

7700 7500 7400 7400 7400

7800 Scale Change Scale Change

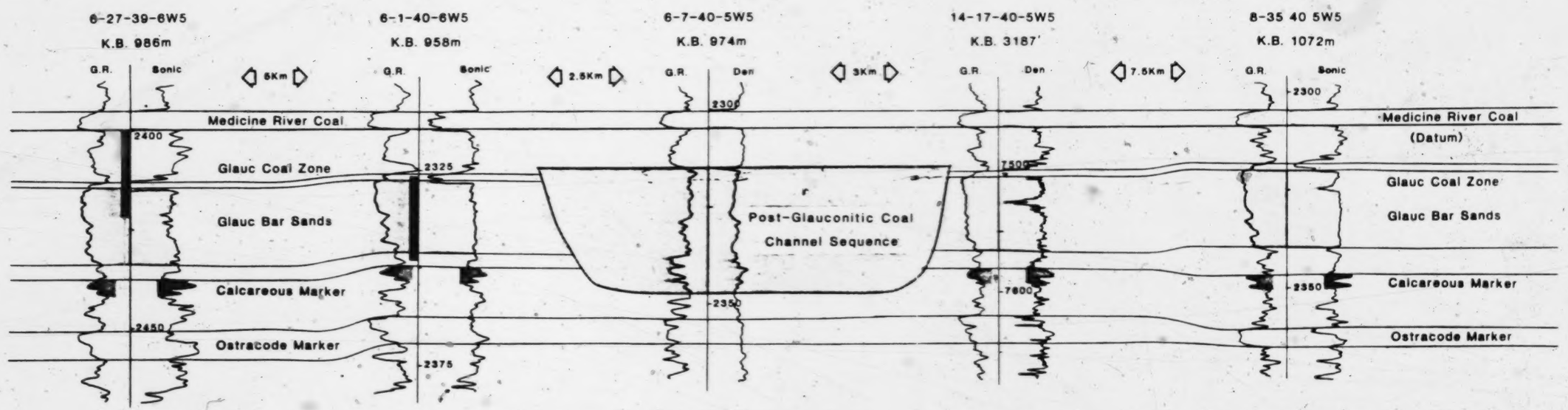


CROSS-SECTION B–B'

R. Strobl
April, 1986.

C
(Southwest)

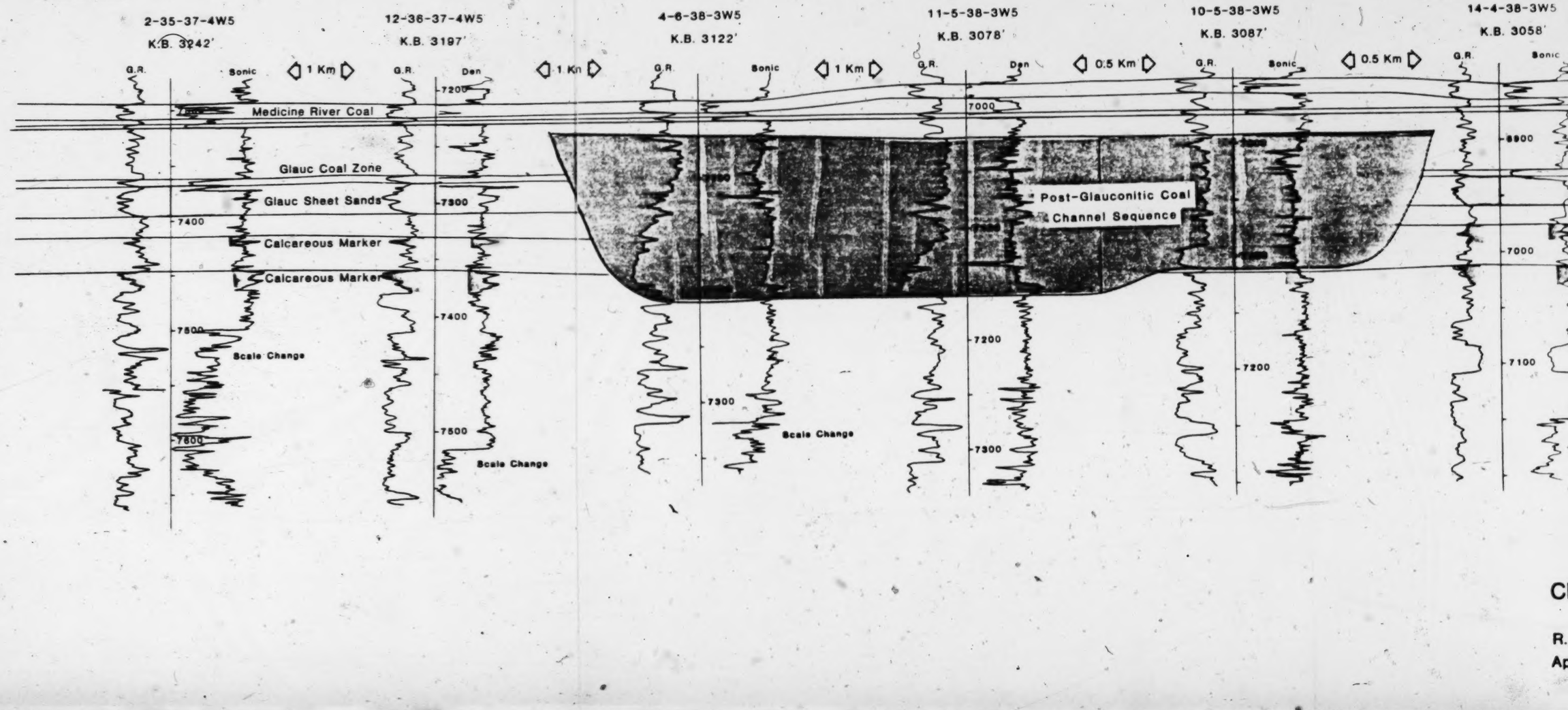
C′
(Northeast)



CROSS-SECTION C-C′

R. Strobl
April, 1986.

D
(Southwest)


2-35-37-4W5
K.B. 3242'
12-36-37-4W5
K.B. 3197'
4-6-38-3W5
K.B. 3122'
11-5-38-3W5
K.B. 3078'
10-5-38-3W5
K.B. 3087'
14-4-38-3W5
K.B. 3058'
G.R.
Sonic
Den
1 Km
0.5 Km
Medicine River Coal
Glauc Coal Zone
Glauc Sheet Sands
Calcareous Marker
Calcareous Marker
Post-Glauconitic Coal
& Channel Sequence
7200
7400
7500
7600
7300
7000
7100
8900
Scale Change

D'
(Northeast)

12-36-37-4W5
K.B. 3197'

4-6-38-3W5
K.B. 3122'

11-5-38-3W5
K.B. 3078'

10-5-38-3W5
K.B. 3087'

14-4-38-3W5
K.B. 3058'

12-10-38-3W5
K.B. 3154'

1 Km | G.R. | Den | 1 Km | G.R. | Sonic | 1 Km | G.R. | Den | 0.5 Km | G.R. | Sonic | 0.5 Km | G.R. | Sonic | 1 Km | G.R. | Sonic

ne River Coal
auc Coal Zone
c Sheet Sands
areous Marker
areous Marker

Post-Glauconitic Coal
Channel Sequence

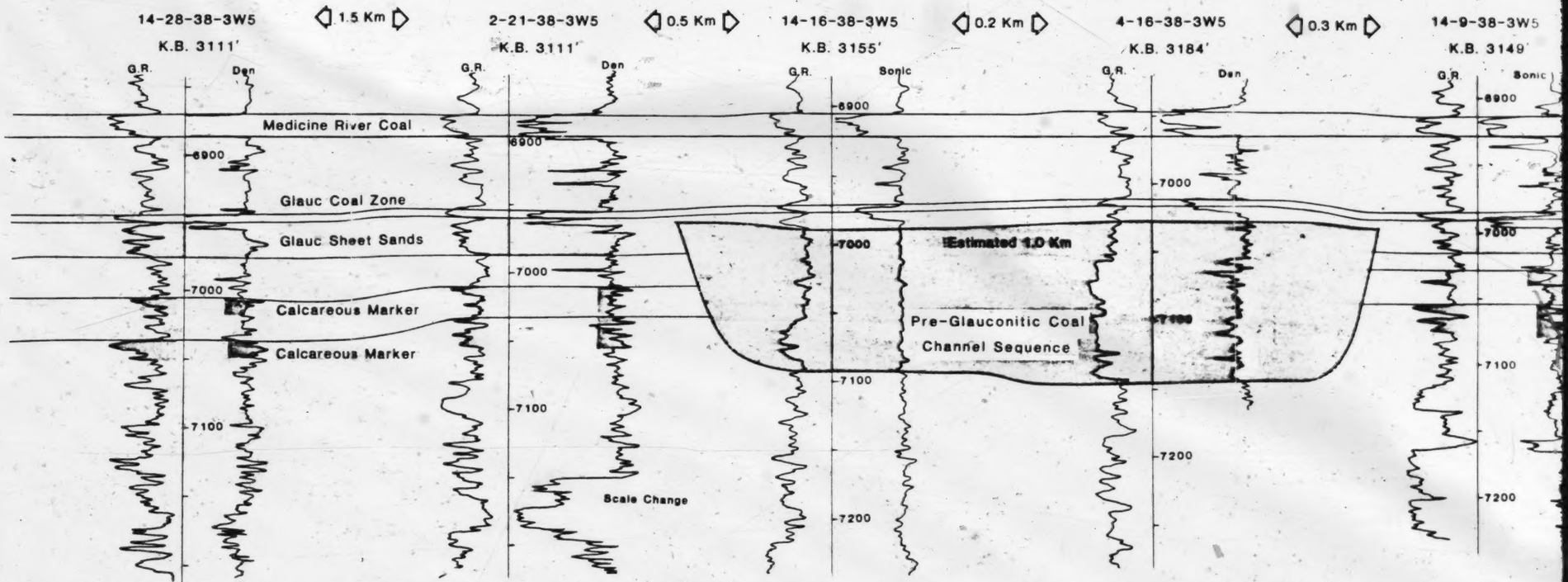
Medicine River Coal
(Datum)
Glauc Coal Zone
Glauc Sheet Sands
Calcareous Marker
Calcareous Marker

7200
7300
7400
7500
Scale Change
7000
7100
7200
7300
Scale Change
6900
7000
7100
Scale Change
6900
7000
7100
7200

CROSS-SECTION D-D'

R. Strobl
April, 1986.

E
(North)

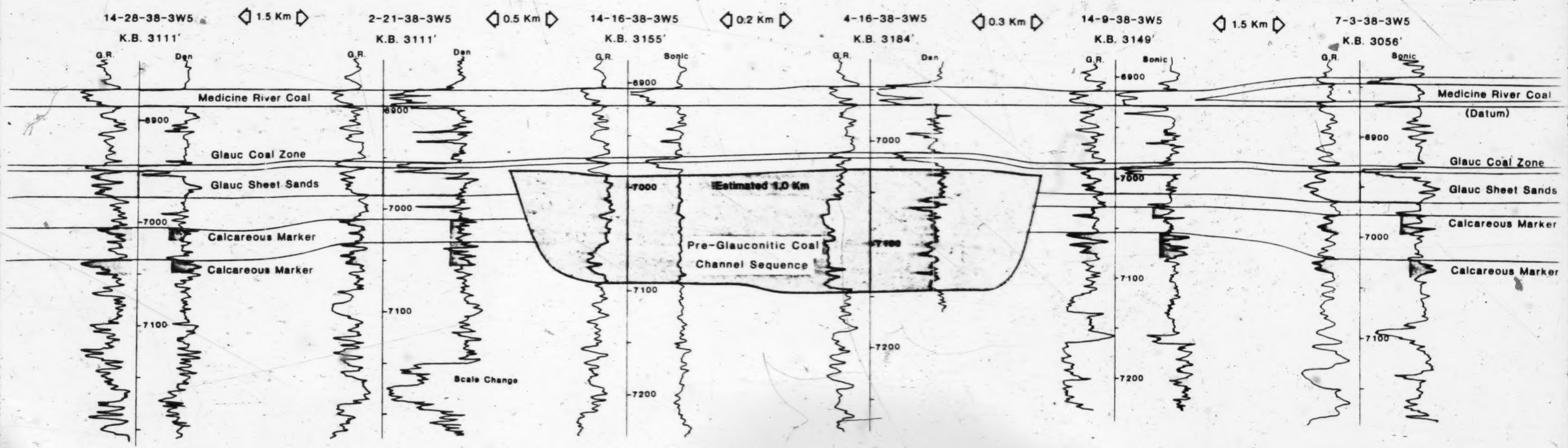


CF

R.
Apr

E
(North)

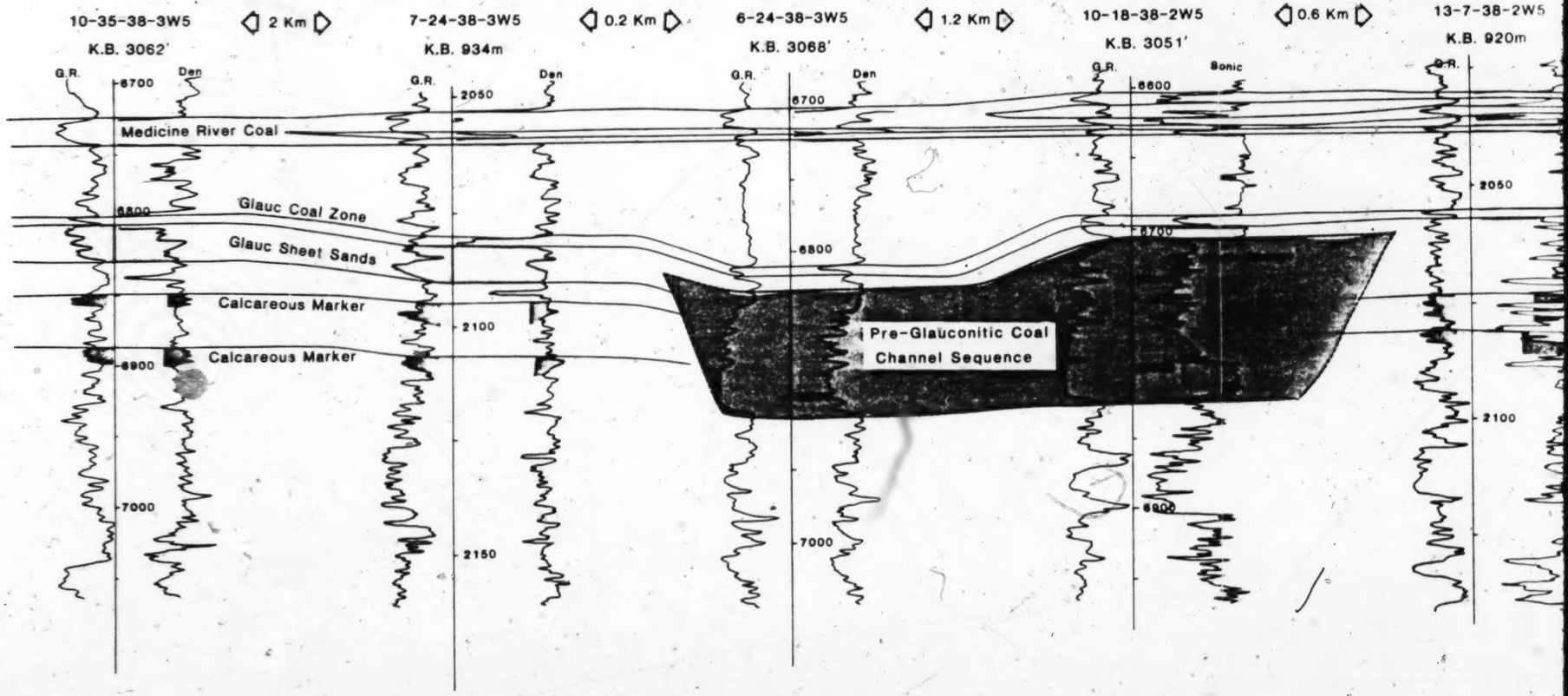
E'
(South)



CROSS-SECTION E-E'

R. Strobl
April, 1986.

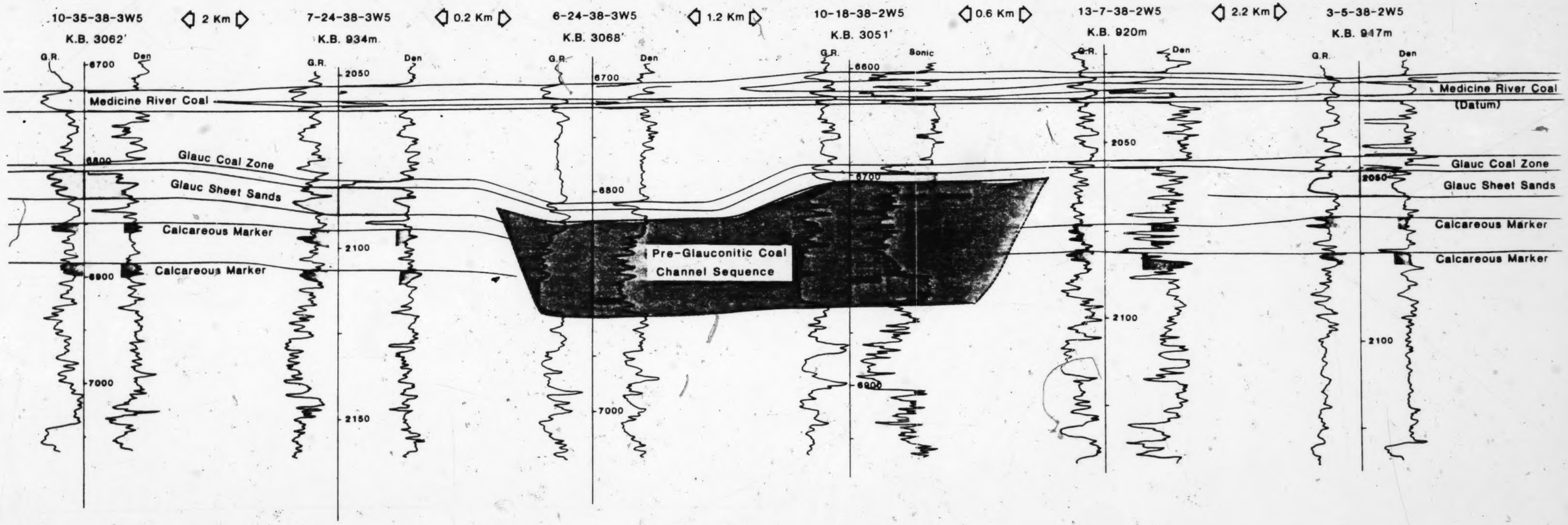
F
(North)


10-35-38-3W5
K.B. 3062'
2 Km
7-24-38-3W5
K.B. 934m
0.2 Km
6-24-38-3W5
K.B. 3068'
1.2 Km
10-18-38-2W5
K.B. 3051'
0.6 Km
13-7-38-2W5
K.B. 920m
G.R.
Den
Sonic
6700
2050
Medicine River Coal
6800
Glauc Coal Zone
Glauc Sheet Sands
Calcareous Marker
Calcareous Marker
6900
7000
2100
2150
Pre-Glauconitic Coal
Channel Sequence

C
R.
A

F
(North)

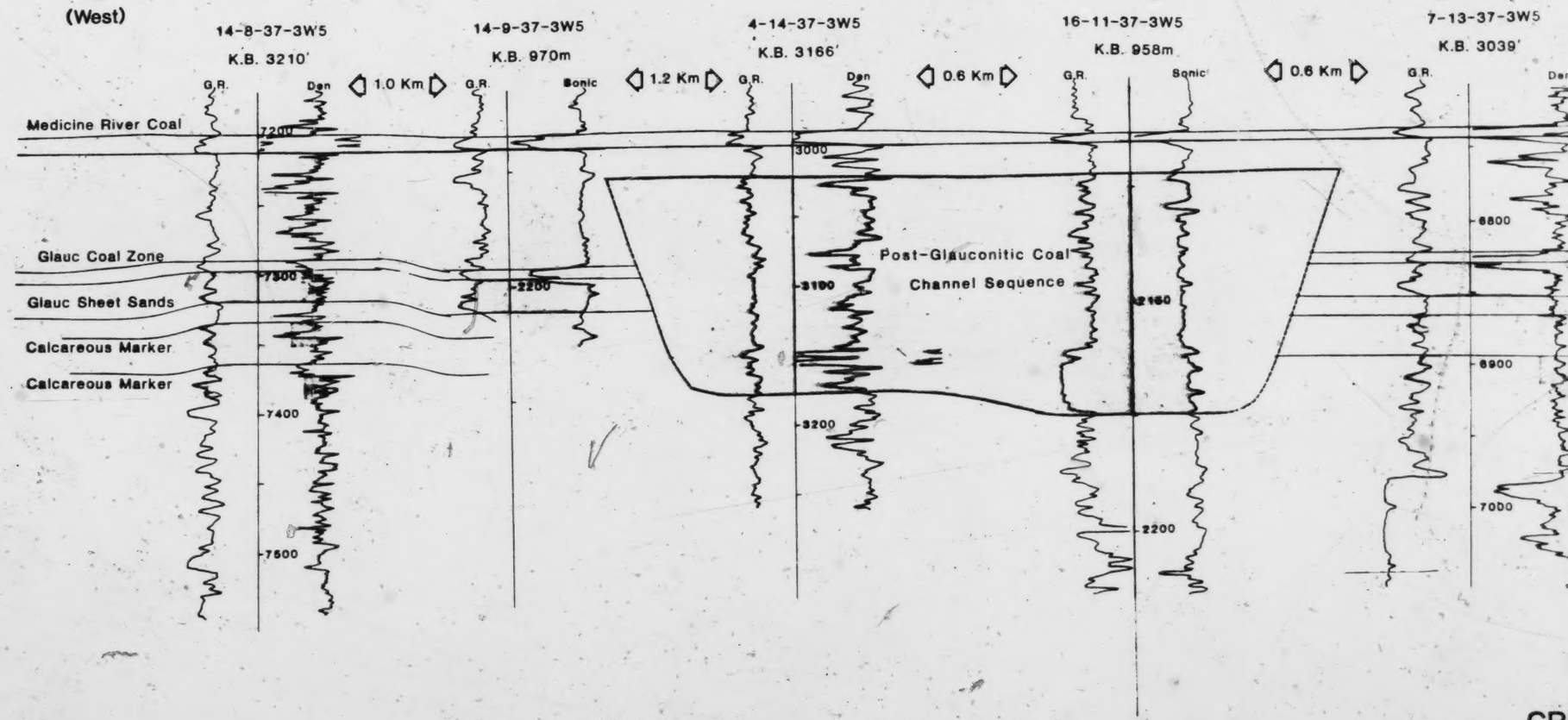
F'
(South)



CROSS-SECTION F-F'

R. Strobl
April, 1986.

G
(West)



CR

R. S

Apri

G
(West)

G'
(East)

14-8-37-3W5
K.B. 3210'

14-9-37-3W5
K.B. 970m

4-14-37-3W5
K.B. 3166'

16-11-37-3W5
K.B. 958m

7-13-37-3W5
K.B. 3039'

7-16-37-2W5
K.B. 2980'

1.0 Km | 1.2 Km | 0.6 Km | 0.6 Km | 3.8 Km

G.R. Den Sonic

Medicine River Coal

Medicine River Coal (Datum)

Glauc Coal Zone

Glauc Sheet Sands

Calcareous Marker

Calcareous Marker

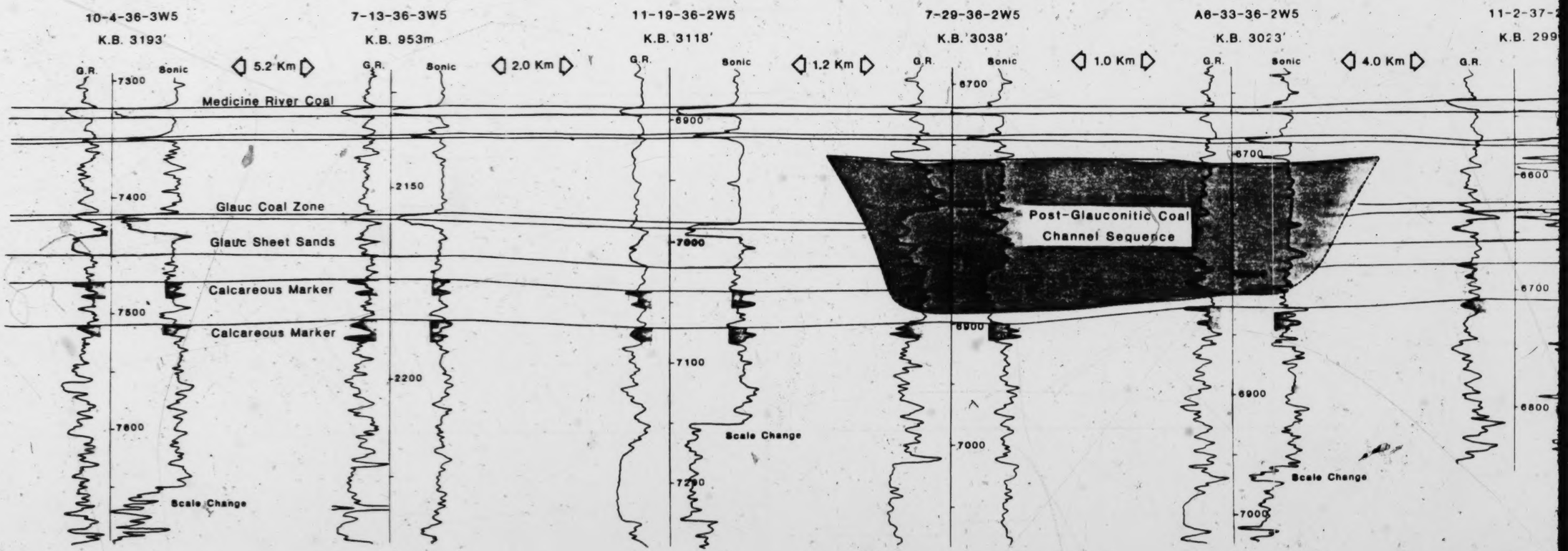
Post-Glauconitic Coal Channel Sequence

7200
7500
7400
7500
2200
3100
3200
2150
2200
6800
6900
7000
6600
6700
6800

CROSS-SECTION G-G'

R. Strobl
April, 1986.

H
(Southwest)


10-4-36-3W5
K.B. 3193'
7-13-36-3W5
K.B. 953m
11-19-36-2W5
K.B. 3118'
7-29-36-2W5
K.B. 3038'
A6-33-36-2W5
K.B. 3023'
11-2-37-
K.B. 299
G.R.
Sonic
5.2 Km
2.0 Km
1.2 Km
1.0 Km
4.0 Km
Medicine River Coal
Glauc Coal Zone
Glauc Sheet Sands
Calcareous Marker
Calcareous Marker
Post-Glauconitic Coal
Channel Sequence
Scale Change
Scale Change
Scale Change
7300
7400
7500
7600
2150
2200
6900
7000
7100
7200
6700
6900
7000
6700
6900
7000
6600
6700
6800

H'
(Northeast)

7-13-36-3W5
K.B. 953m

11-19-36-2W5
K.B. 3118'

7-29-36-2W5
K.B. 3038'

A6-33-36-2W5
K.B. 3023'

11-2-37-2W5
K.B. 2991'

10-18-37-1W5
K.B. 3164'

5.2 Km | 2.0 Km | 1.2 Km | 1.0 Km | 4.0 Km | 5.0 Km

G.R. Sonic | G.R. Sonic | G.R. Sonic | G.R. Sonic | G.R. Den | G.R. Den

edicine River Coal

Glauc Coal Zone

Glauc Sheet Sands

Calcareous Marker

Calcareous Marker

hange

2150

2200

6900

7000

7100

7200

Scale Change

6700

6900

7000

Post-Glauconitic Coal
Channel Sequence

6700

6800

6900

7000

Scale Change

Medicine River Coal
(Datum)

6600

6700

6800

6900

Glauc Coal Zone

Glauc Sheet Sands

Calcareous Marker

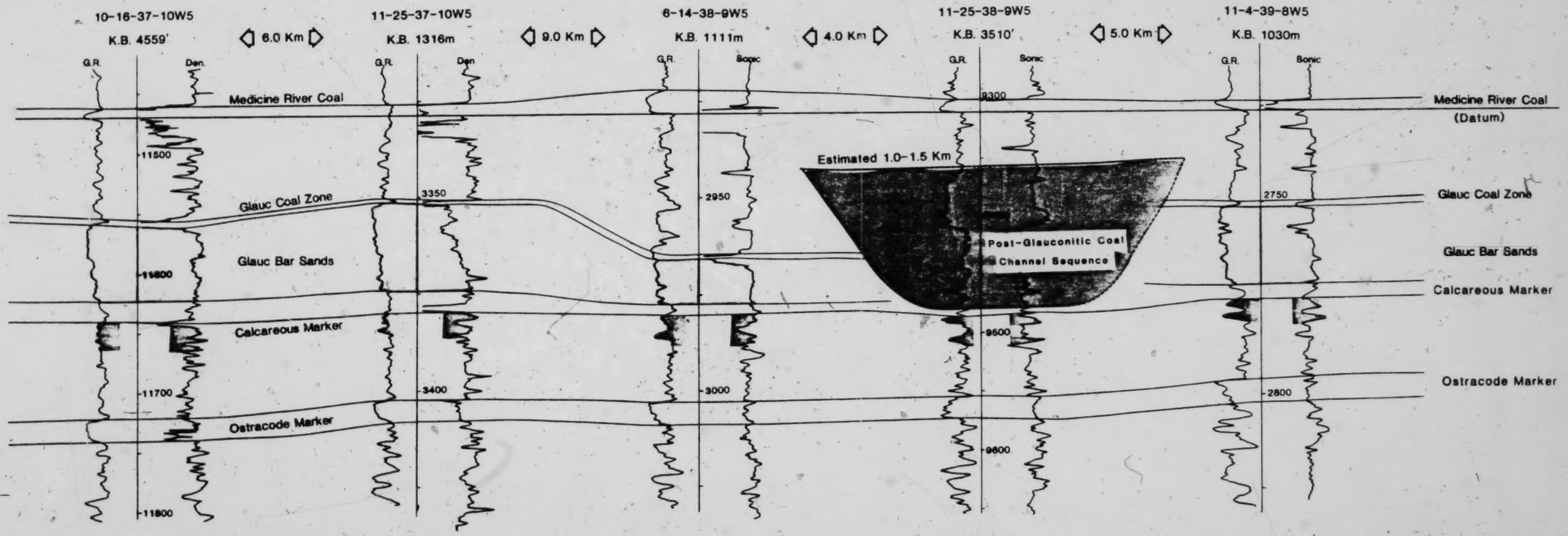
Calcareous Marker

CROSS-SECTION H-H'

R. Strobl
April, 1986.

I
(Southwest)

I'
(Northeast)

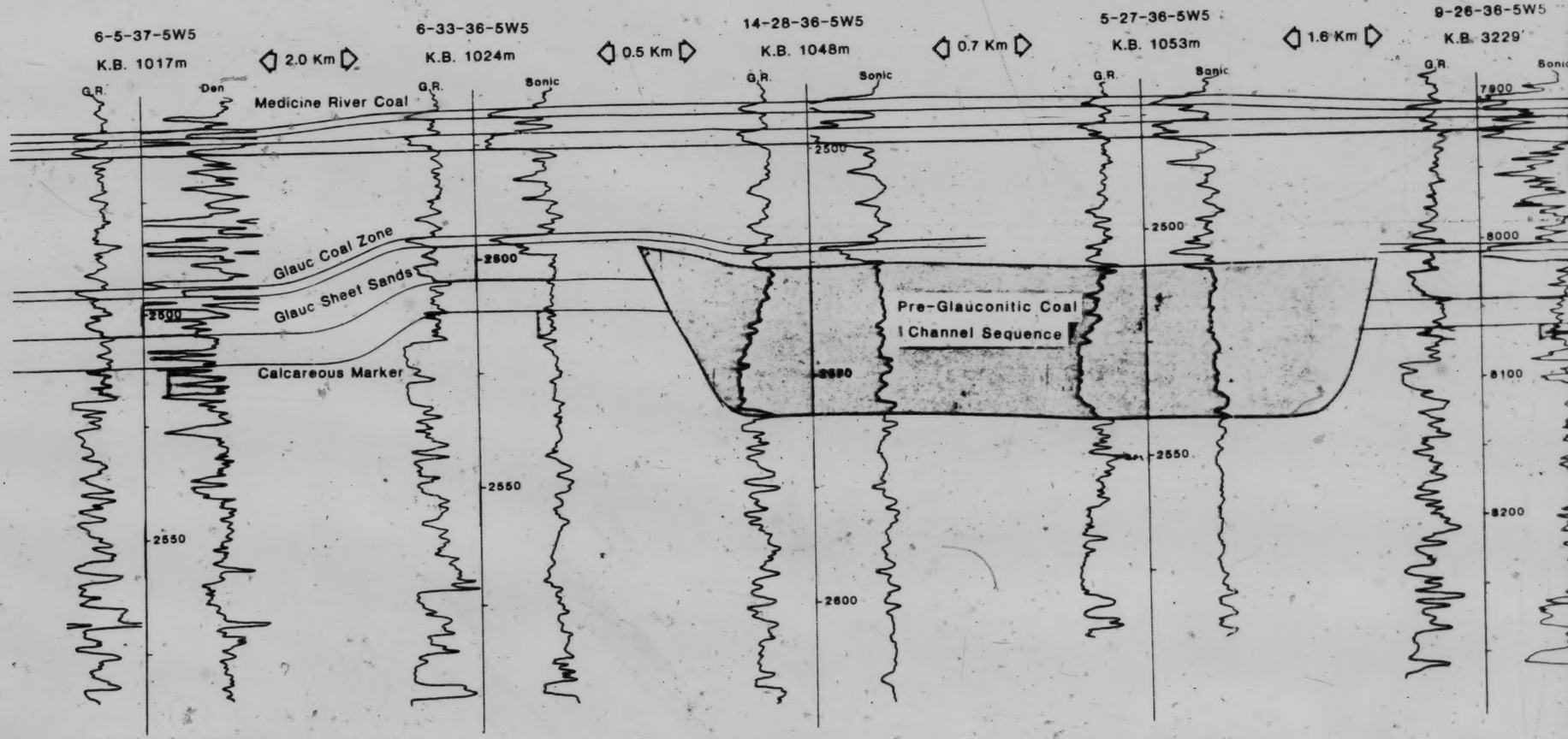


CROSS-SECTION I-I'

R. Strobl
April, 1986.

J
(Northwest)

(Southeast)



J
(Northwest)

J'
(East)

(Southeast)

6-5-37-5W5
K.B. 1017m

2.0 Km

6-33-36-5W5
K.B. 1024m

0.5 Km

14-28-36-5W5
K.B. 1048m

0.7 Km

5-27-36-5W5
K.B. 1053m

1.6 Km

9-26-36-5W5
K.B. 3229'

1.5 Km

11-25-36-5W5
K.B. 1004m

G.R. Den

G.R. Sonic

Medicine River Coal

Glauc Coal Zone

Glauc Sheet Sands

Calcareous Marker

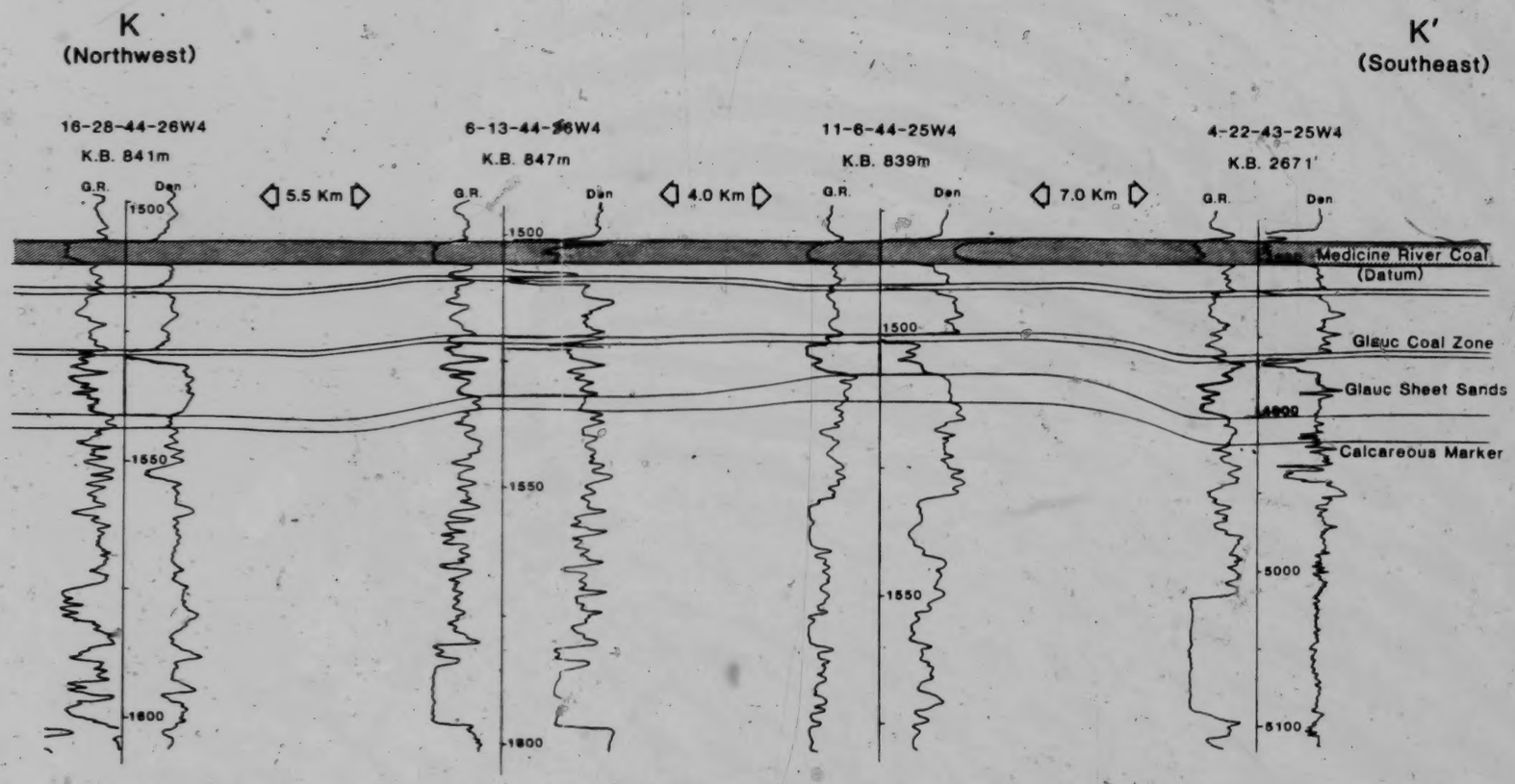
Pre-Glauconitic Coal
Channel Sequence

2500
2550
2600
7900
8000
8100
8200
2400
2450

(Datum)

CROSS-SECTION J-J'

R. Strobl
April, 1986.



CROSS-SECTION K-K'

R. Strobl
April, 1986.

(NORTH)

6-7-48-13W5
K.B. 1079m

6-32-46-13W5
K.B. 3625'

10-14-46-13W5
K.B. 3466'

11-9-45-12W5
K.B. 3274'

7-8-44-11W5
K.B. 1131m

10-13-43-11W
K.B. 3389'

G.R. Sonic G.R. Sonic G.R. Sonic G.R. Sonic G.R. Sonic G.R. Den

8 Km 5 km 8 Km 8 Km 6.5 Km

Top of Mannville Fm.

Coarsening Upward Sequences

Coarsening Upward Sequences

Upper Medicine River Coal

Medicine River Coal (Datum)

Upper Mannville Bar Lithosome

(Falher equivalent?)

-44-11W5
B. 1131m

10-13-43-11W5
K.B. 3389'

4-26-42-11W5
K.B. 3576'

11-29-41-10W5
K.B. 1083m

10-15-41-10W5
K.B. 3359'

11-30-40-9W5
K.B. 3403'

4-2-40-9W5
K.B. 3477'

Sonic G.R. Den G.R. Sonic G.R. Sonic G.R. Sonic G.R. Sonic G.R. Sonic

6.5 Km 5 Km 6.5 Km 3 Km 5 Km 6 Km

2650 2700 2750 8600 8700 8800 8900 9000 9100 9200 9300 8900 9000 9100 9400 9500 2750 2800 2850 2900 8700 8800 8900 9000 9100 9200 9300 8700 8800 8900 9000 9100 9200 9300

11-30-40-9W5
K.B. 3403'

4-2-40-9W5
K.B. 3477'

8-9-39-8W5
K.B. 1031m

6-8-38-7W5
K.B. 1027m

7-31-37-7W5
K.B. 3553'

6-35-36-7W5
K.B. 3558'

8-17-36
K.B. 10

G.R. Sonic 6 Km G.R. Sonic 7 Km G.R. Sonic 8 Km G.R. Sonic 2 Km G.R. Den 8 Km G.R. Den 5 Km G.R.

8700 8800 8900 9000 9100 9200 9300

2550 2600 2650 2700

Top of Mannville Fm.

Upper Medicine River Coal

Medicine River Coal (Datum)

Glauconitic Coal Zone

Sheet Sands

6-8-38-7W5
K.B. 1027m

7-31-37-7W5
K.B. 3553'

6-35-36-7W5
K.B. 3558'

8-17-36-6W5
K.B. 1086m

6-4-36-6W5
K.B. 1148m

(SOUTH)

8 Km | 2 Km | 8 Km | 5 Km | 2 Km

G.R. | Sonic | G.R. | Den | G.R. | Den | G.R. | Sonic | G.R. | Sonic

Top of Mannville Fm.

Upper Medicine River Coal

Medicine River Coal (Datum)

Glauconitic Coal Zone

8600 8700 8800 8900 9000 9100 9200

2550 2600 2650 2700

Upper Medicine River Coal

Medicine River Coal (Datum)

Upper Mannville Bar Lithosome

(Falher equivalent?)

Bigoray Bar Lithosome

Pre-Mannville Unconformity

Fernie Fm.

Rock Creek Fm.

Bigoray Bar
Lithosome

Pre-Mannville
Unconformity

Fernie Fm.

Rock Creek Fm.

Upper Medicine River Coal

Medicine River Coal (Datum)

Glauconitic Coal Zone

Hoadley Bar Lithosome

Sheet Sands Lithosome

Ostracode Marker

Fernie Fm

Rock Creek Fm.

CROSS–SECTION

R. STROBL

APRIL, 1986.

Upper Medicine River Coal

Medicine River Coal (Datum)

Glauconitic Coal Zone

Hoadley Bar Lithosome

Sheet Sands Lithosome

stracode Marker

Fernie Fm

Rock Creek Fm.

CROSS–SECTION L-L

R. STROBL

APRIL, 1986.